Nos. 22-1350, -1351

IN THE

United States Court of Appeals for the Federal Circuit

APPLE INC.,

Appellant,

v.

COREPHOTONICS, LTD.,

Appellee.

On Appeal from the United States Patent and Trademark Office, Patent Trial and Appeal Board
Nos. IPR2020-00905 and IPR2020-00906

OPENING BRIEF OF APPELLANT APPLE INC.

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CLAIM LANGUAGE AT ISSUE

U.S. Patent No. 10,225,479

1. A dual-aperture digital camera for imaging an object or scene, comprising:

> a) a Wide camera comprising a Wide lens and a Wide image sensor, the Wide camera having a respective field of view FOV_W and being operative to provide a Wide image of the object or scene;
>
> b) a Tele camera comprising a Tele lens and a Tele image sensor, the Tele camera having a respective field of view FOV_T narrower than FOV_W and being operative to provide a Tele image of the object or scene, wherein the Tele lens has a respective effective focal length EFL_T and total track length TTL_T fulfilling the condition $EFL_T/TTL_T>1$;
>
> c) a first autofocus (AF) mechanism coupled mechanically to, and used to perform an AF action on the Wide lens;
>
> d) a second AF mechanism coupled mechanically to, and used to perform an AF action on the Tele lens; and
>
> e) a camera controller operatively coupled to the first and second AF mechanisms and to the Wide and Tele image sensors and configured to control the AF mechanisms and to process the Wide and Tele images to create a fused image, wherein areas in the Tele image that are not focused are not combined with the Wide image to create the fused image and wherein the camera controller is further operative to output the *fused image with a point of view (POV) of the Wide camera* by mapping Tele image pixels to matching pixels within the Wide image.

19. A dual-aperture digital camera for imaging an object or scene, comprising:

a) a Wide camera comprising a Wide lens and a Wide image sensor, the Wide camera having a respective field of view FOV_W and being operative to provide a Wide image of the object or scene;

b) a Tele camera comprising a Tele lens and a Tele image sensor, the Tele camera having a respective field of view FOV_T narrower than FOV_W and being operative to provide a Tele image of the object or scene, wherein the Tele lens has a respective effective focal length EFL_T and total track length TTL_T fulfilling the condition $EFL_T/TTL_T>1$;

c) a first autofocus (AF) mechanism coupled mechanically to, and used to perform an AF action on the Wide lens;

d) a second AF mechanism coupled mechanically to, and used to perform an AF action on the Tele lens, wherein the Wide and Tele lenses have different F numbers $F\#_{Wide}$ and $F\#_{Tele}$, wherein the Wide and Tele image sensors have pixels with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ wherein Pixel $size_{Wide}$ is not equal to Pixel $size_{Tele}$, and wherein the Tele camera has a Tele camera depth of field (DOF_T) shallower than a DOF of the Wide camera (DOF_W); and

e) a camera controller operatively coupled to the first and second AF mechanisms and to the Wide and Tele image sensors and configured to control the AF mechanisms, to process the Wide and Tele images to find translations between matching points in the images to calculate depth information and to create a fused image suited for portrait photos, the fused image having a DOF shallower than DOF_T and having a blurred background.

UNITED STATES COURT OF APPEALS
FOR THE FEDERAL CIRCUIT

CERTIFICATE OF INTEREST

Case Number 22-1350, -1351

Short Case Caption Apple Inc. v. Corephotonics, Ltd.

Filing Party/Entity Apple Inc.

Instructions: Complete each section of the form. In answering items 2 and 3, be specific as to which represented entities the answers apply; lack of specificity may result in non-compliance. **Please enter only one item per box; attach additional pages as needed and check the relevant box**. Counsel must immediately file an amended Certificate of Interest if information changes. Fed. Cir. R. 47.4(b).

I certify the following information and any attached sheets are accurate and complete to the best of my knowledge.

Date: 06/24/2022

Signature: /s/ Elizabeth R. Moulton

Name: Elizabeth R. Moulton

1. Represented Entities. Fed. Cir. R. 47.4(a)(1).	**2. Real Party in Interest.** Fed. Cir. R. 47.4(a)(2).	**3. Parent Corporations and Stockholders.** Fed. Cir. R. 47.4(a)(3).
Provide the full names of all entities represented by undersigned counsel in this case.	Provide the full names of all real parties in interest for the entities. Do not list the real parties if they are the same as the entities. ☑ None/Not Applicable	Provide the full names of all parent corporations for the entities and all publicly held companies that own 10% or more stock in the entities. ☑ None/Not Applicable
Apple Inc.		

☐ Additional pages attached

4. Legal Representatives. List all law firms, partners, and associates that (a) appeared for the entities in the originating court or agency or (b) are expected to appear in this court for the entities. Do not include those who have already entered an appearance in this court. Fed. Cir. R. 47.4(a)(4).

☐ None/Not Applicable ☐ Additional pages attached

Haynes and Boone, LLP	Michael S. Parsons	Andrew S. Ehmke
Jordan Maucotel	Hong Shi	David W. O'Brien
Bethany Love	Stephanie Sivinski	

5. Related Cases. Provide the case titles and numbers of any case known to be pending in this court or any other court or agency that will directly affect or be directly affected by this court's decision in the pending appeal. Do not include the originating case number(s) for this case. Fed. Cir. R. 47.4(a)(5). See also Fed. Cir. R. 47.5(b).

☐ None/Not Applicable ☐ Additional pages attached

Corephotonics, Ltd. v. Apple Inc. No. 5:19-cv-04809-EJD (N.D. Cal.)		

6. Organizational Victims and Bankruptcy Cases. Provide any information required under Fed. R. App. P. 26.1(b) (organizational victims in criminal cases) and 26.1(c) (bankruptcy case debtors and trustees). Fed. Cir. R. 47.4(a)(6).

☑ None/Not Applicable ☐ Additional pages attached

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STATEMENT OF RELATED CASES

No appeal in or from the same proceeding was previously before this Court or any other appellate court.

Counsel is aware that the following case may directly affect or be directly affected by this Court's decision in the pending appeal: *Corephotonics, Ltd. v. Apple Inc.*, No. 3:19-cv-04809-JD (N.D. Cal.).

Pursuant to this Court's orders, the following cases have been designated as companions to this appeal:

Apple Inc. v. Corephotonics, Ltd., No.	22-1324
Corephotonics, Ltd. v. Apple Inc., Nos.	22-1340, 22-1341
Corephotonics, Ltd. v. Apple Inc., Nos.	22-1455, 22-1456

The following case is related to this appeal:

Apple Inc. v. Corephotonics, Ltd., Nos.	22-1325, 22-1327, 22-1453, 22-1457

INTRODUCTION

Today's iPhones have multiple camera lenses. Different lenses (for example, a wide-angle lens and a telephoto lens) capture digital images with different characteristics, and software on the iPhone stitches the images together. By combining the different images, you can get a photo in which both close up and far away objects appear in sharp focus. You can also achieve special effects, like "portrait mode," where the subject of the image is in focus and the rest of the image appears blurry. Using multiple lenses within the same camera to create these different effects has long been known in the prior art.

This appeal covers two separate inter partes review proceedings of different sets of claims of Corephotonics's U.S. Patent No. 10,225,479. Both sets of claims require a digital camera with a wide-angle lens and a telephoto lens, and a camera controller with programming that combines the images from each lens to create a combined image with certain characteristics. Apple's inter partes review challenges showed that both the physical lenses and the image processing steps claimed in the patent were well known in the art, and that a person of ordinary

skill in the art would have combined the prior art to make the claimed invention.

The Patent Trial and Appeal Board made separate errors in each proceeding. In the first, the Board made a quintessential claim construction error and limited the claims to one particular embodiment, despite no limiting language in the claim or the specification. Regardless, Corephotonics essentially conceded that the key prior art teaches the limitation in question, even under Corephotonics's cramped construction. In the second, the Board latched on to an inconsequential data-entry error by Apple's expert that even Corephotonics never suggested was material to the patentability analysis. The result is that neither Final Written Decision is supported by substantial evidence, and both should be reversed or vacated and remanded for further proceedings.

JURISDICTIONAL STATEMENT

Apple filed two petitions for inter partes review of the '479 patent. *See* Appx79-157; Appx723-804; 35 U.S.C. §§ 311, 312; 37 C.F.R. § 42.104. The Board instituted proceedings. Appx196; Appx839. On November 8, 2021, the Board issued a Final Written Decision holding

claims 1-16, 18, 23-38, and 40 not unpatentable, Appx1-24 (-905 IPR), and a Final Written Decision holding claims 19-22 not unpatentable, Appx25-45 (-906 IPR). On January 10, 2022, Apple timely filed its notices of appeal. *See* Appx693-698; Appx1326-1331; 35 U.S.C. § 142; 37 C.F.R. § 90.3(a)(1); Fed. Cir. R. 15(a)(1). This Court has jurisdiction pursuant to 28 U.S.C. § 1295(a)(4)(A).

STATEMENT OF THE ISSUES

1. Did the Board err in holding claims 1-16, 18, 23-38, and 40 not unpatentable as obvious under Parulski after applying an improper claim construction?

2. Did the Board err in holding claims 19-22 not unpatentable as obvious when it found no motivation to combine Parulski and Ogata on the basis of a data-entry error in an expert's declaration when no party argued that error was material to the obviousness inquiry?

STATEMENT OF THE CASE

Consumers desire small but high-performance digital cameras.

Consumers today demand small, handheld cameras that generate high quality images. The demand for these convenient and high-performance cameras is not new; over the years people have sought different ways to deliver high-end camera performance with

increasingly small designs. Much of that work has focused on the lens (or lenses) in a camera, to exploit certain traits of the images that different lenses capture.

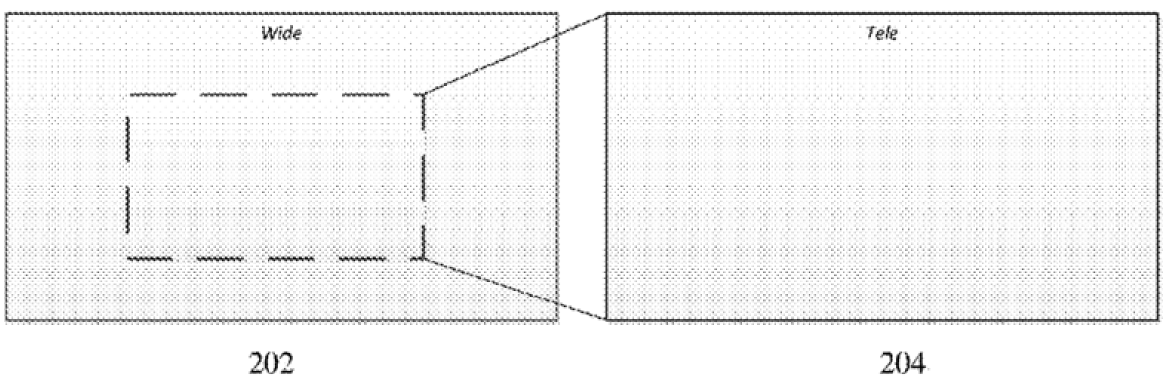
A camera lens assembly (which is usually made up of multiple lenses stacked together) has unique characteristics that affect the image produced by the lens. Two particular image enhancements are relevant to this appeal. The first is the zoom feature: the ability to provide different magnifications of the same scene. Appx64 (1:44-49). The second is an aesthetic visual effect called "bokeh," where the background of a photograph is out of focus, and thus blurrier than the photograph's foreground. Appx2002. This blurred-background style of photograph is common in portraits, to make the subject of the portrait stand out. Appx71 (15:30-32).

A foundational lens characteristic critical to both zoom and bokeh is focal length. Although not a measurement of the actual length of a lens, focal length dictates the angle of what is within the view of the lens. *See, e.g.*, Appx5386; Appx4269-4270. That angle, in turn, affects the magnification of the objects within the view of the lens. Appx64 (1:39-43). As focal length increases, the angle of view narrows and

magnification increases. *E.g.*, Appx64 (2:17-32). In other words, fewer objects are within the view of the lens, but those objects appear larger—think of binoculars.

The "field of view," or FOV, is the name for the lens angle dictated by the lens's focal length; it is a measurement expressed in degrees. Appx2718. The term field of view is also used in a less technical sense to refer to the scene visible through the lens of the camera. Appx5385; Appx3912.

Below is an example of FOV:



Appx57 (Fig. 2).

The image on the left is the field of view from a "wide-angle" lens, also simply called a wide lens. A wide lens has a relatively low focal length, which means it has a wide angle of view—thus its name—and a lower magnification, or zoom. Appx64 (2:23-25). In other words, it

depicts a large scene from far away, and is typically used for things like landscape photography.

The image on the right is the field of view from a "telephoto" or "tele" lens. A tele lens has a higher focal length, which means it has a narrower field of view but the image it captures is shown at a higher level of magnification. Appx64 (2:23-25). So in the image above, you see that that the tele lens is capturing a magnified version of the center of the scene captured by the wide lens. Based on these principles, zooming was traditionally accomplished by physically altering the focal length of the lens to increase or decrease the magnification of the image as the lens moved. Appx64 (1:44-51).

Focal length also affects the resulting image's "depth of field"—the portion of a photograph that appears sharp or in focus. Appx1987 (7:56-59). If most or all of the photograph is out of focus or blurry, the depth of field is called "shallow." Appx65 (4:18-38). If most or all of the photograph is in focus, the depth of field is called "deep." The greater the focal length, the shallower the depth of field—meaning an image captured by a tele lens has a shallower depth of field than an image captured by a wide lens. Appx65 (4:23-30). As a result, bokeh is

traditionally achieved using a lens with a larger focal length and thus a shallow depth of field. Appx65 (4:18-20). Because a tele lens has a longer focal length than a wide lens, *see supra* at 5-6, an image captured with a tele lens will have a shallower depth of field and thus more aesthetic blurring or bokeh than an image captured with a wide lens. Appx65 (4:25-27).

As consumers demanded smaller cameras, figuring out how to provide high-quality zoom and bokeh effects with short, fixed focal length lenses was initially a challenge. Because bokeh is tied to focal length, it has traditionally been difficult to replicate in digital cameras with short focal lengths. Appx65 (4:20-23). As for zooming, there is an alternative to the mechanical zoom process called "digital zooming": Rather than adjusting the focal length of a lens, a digital camera processor "crops the image and interpolates between the pixels." Appx64 (1:53-58). Although the resulting image is magnified, it has a lower resolution. Appx64 (1:53-58).

A space-efficient method for improving the quality of a standalone digital or cellphone camera's output image is use of a dual-aperture (*i.e.*, two-opening) camera unit with two camera lenses. If each sub-camera

uses a lens with a different focal length, each will capture an image with a different field of view and depth of field: The lens with the smaller focal length (*e.g.*, a wide lens) will capture a broader scene with more objects in sharp focus, while the lens with the larger focal length (*e.g.*, a tele lens) will be zoomed in for a closer look at a subset of the scene, with objects in the background out of focus. *See supra* at 4-6.

The field of view and depth of field are not the only differences between the two images, however. Every image captured by a given lens has a particular "point of view." Appx66 (5:10-33). There are two aspects to an image's point of view. The first is "position," and refers to where an object appears within the frame. Appx66 (5:10-13). Imagine looking through a camera at a tree in a large field. By physically moving the camera, you can make the tree appear in the center of the frame, in the upper-left corner, on the center-right, etc. You can also change where the tree appears in the frame by zooming in or out: Zoomed out, the tree might be a tiny speck in the middle, but zoomed in, the tree might take up the whole frame. Thus, position point of view can be affected by either the placement of the camera in space or the focal length (and thus field of view) of the lens (or both). Appx1865.

The second type of point of view is "perspective," also called "shape," and refers to the contour of an object as it appears in the image. Appx66 (5:10-13). Imagine the tree again: Changing the angle, or perspective, from which you are viewing the tree (for example, walking to the other side) will alter which part of the tree you see, and thus its shape. Unlike position POV, however, perspective POV is unaffected by zooming in or out—the shape of the object remains the same no matter how magnified the image. Appx3912.

To illustrate POV, consider the image below.

(a) (b)

Appx2400 (red arrows added).

In these images, the "position" is slightly different in that you can see more of the birdhouse below the perch in the image on the right.

And the "perspective" or "shape" is different, in that the chimney on the birdhouse overlaps only slightly with the blue painting in the image on the left, but overlaps much more in the image on the right. That is because the two images were taken with the camera at slightly different angles.[1] Similarly, the images captured by each of the cameras in a dual-aperture camera will have a different perspective and position.

The prior art discloses a dual-aperture camera designed to deliver high-end performance in minimal space.

Digital image-processing techniques can combine the two images obtained from a dual-aperture camera, despite their differences, in various ways for an enhanced output image. U.S. Patent No. 7,859,588 to Parulski teaches such image processing techniques for a dual-lens camera. Parulski discloses "a digital camera that uses multiple lenses and image sensors to provide an improved imaging capability." Appx1984 (1:8-10). The camera may operate in both still and video

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[1] As another example, if you "hold your finger vertically in front of your eyes and close each eye alternately," "the finger jumps left and right relative to the background of the scene." Appx2401. In addition to being in a different position relative to the background, your finger is being viewed from a different perspective, and thus has a slightly different shape. The closer an object is to the camera (or the eyes), the larger and more noticeable point-of-view differences are. Appx2400.

modes to produce both "still images and motion video images." Appx1989 (12:36-41). Parulski teaches both a standalone digital camera and also a cellphone camera:

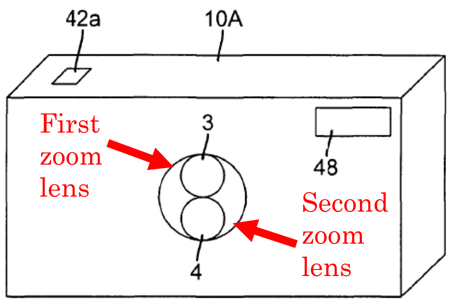

FIG. 2A

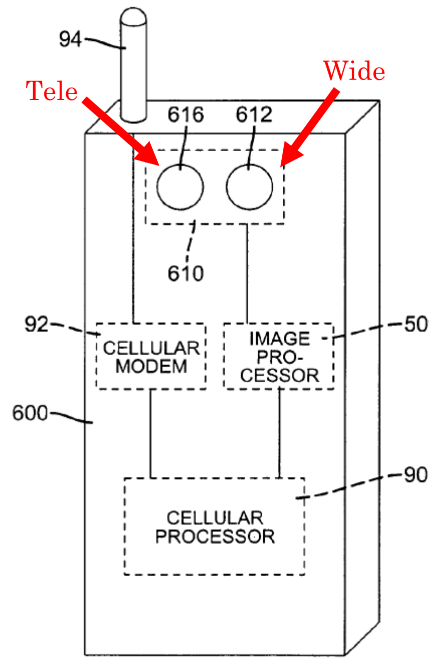

FIG. 15B

See Appx1956, Appx1969 (annotation added).

The standalone digital camera embodiment depicted in Figure 2A contains two adjustable-focus lenses, but Parulski states that "one (or both) of the zoom lenses 3 and 4 could be replaced with a fixed focal length lens." Appx1990 (13:4-6). With respect to the cellphone camera embodiment depicted in Figure 15B, lens 612 is "preferably a fixed focal length wide angle lens" and lens 616 is "preferably a fixed focal length telephoto lens." Appx1995 (23:36-39). In both embodiments, the two

lenses capture "substantially the same scene, albeit typically with different fields of view." Appx1990 (13:6-9); *see also* Appx1995 (23:40-43). Both embodiments also have image sensors situated behind the lenses. Appx1955 (Fig. 1).

Parulski teaches "utiliz[ing] one of the images from [the] dual-lens camera as a secondary image that can be used to modify the other, primary image and thereby generate an enhanced primary image." Appx1987 (7:32-35).

Two enhancements taught by Parulski are at issue here. The first results in a *sharper* image, where more of the scene is in clearer focus. *See* Appx1994 (22:37-42), Appx1997 (28:52-53) (data from the "secondary" Tele camera image may be used to "sharpen portions of the primary [Wide] image that are positioned near the [Tele] focus distance," resulting in a "combined … image with a broadened depth of field"). The second results in a *blurrier* image, where more of the scene is out-of-focus to create a bokeh effect emphasizing the subject of the photograph, which remains in focus. *See* Appx1994 (21:27-44).

Combining the images from each of the two sub-cameras requires more than a simple cut-and-paste. That is because while the two sub-

cameras may be oriented to look at the same portion of a scene, there are two key differences between them. First, the Wide and Tele lenses have different focal lengths, and thus different (but overlapping) fields of view. Appx1990 (13:6-9), Appx1995 (23:40-43); *see also supra* at 5-6. Second, the Wide and Tele lenses are spaced slightly apart. As a result of these two differences, the images captured by each of the sub-cameras will have different points of view. *See supra* at 8-10. Thus, before the images can be combined, they "must be modified to make [them] comparable" to one another. Appx1993 (19:63-20:1).

Parulski teaches an image-processing technique that enables use of data from one image to enhance the other. This involves matching pixels from the Tele sub-camera image to a matching set of pixels from the Wide sub-camera image to produce a "range map." Appx1993 (19:49-20:15). The range map enables "object identification within the image," such that the "shape of the object can be defined." Appx1993 (20:51-59). And the resulting "range data" is used to "sharpen" an object in the foreground of the Wide image that would otherwise be out-of-focus, or conversely, "blur[] portions of the output image … that lie

outside of a desired depth of field for a featured portion of the image." Appx1994 (21:7-44).

The prior art also discloses wide and tele lenses that can be scaled for use in Parulski's dual-aperture camera.

Parulski is focused on the imaging processing techniques for combining the wide and tele images. It does not detail the lens prescription or image sensor data for either the Wide or Tele lenses used in the camera, and does not require any particular lens design. *See generally* Appx1953-2001. So, for example, Parulski does not dictate any specific field of view angle or focal length for its lenses. Nor does it address the material from which those lenses should be made (a characteristic reflected in the "Abbe number" of the lens).[2] Nor does it specify the "brightness ratio," also called "f-number," of the lens.[3] It instructs instead that any "[e]lements not specifically shown or

[2] The "Abbe number is an approximate measure of how a material's index of refraction depends on the frequency of light passing through it." Appx36.

[3] The f-number of a lens dictates how much light reaches the image sensor in a given time and thus influences how bright the resulting image is. Appx4783-4784; Appx4817. The lower the f-number, the brighter the image captured by the camera in a given amount of time. Appx4817-4818.

described herein may be selected from those known in the art." Appx1988 (10:2-4).

Specific designs for fixed-focal length, dual-lens systems appropriate for digital equipment like standalone digital cameras are described in other prior art references. For instance, Japanese Patent Pub. No. 2013-106289 (Konno), issued in 2013, discloses a dual-lens assembly: "single-focus first and second imaging optical systems that face the same direction," with different focal lengths and specific lens designs. Appx2461-2462. Konno includes an embodiment with Tele and Wide lenses appropriate for a "slim and small-sized imaging apparatus." Appx2463; Appx2467-2469. Japanese Patent Pub. No. S58-62609 (Kawamura), issued in 1983, describes a "telephoto lens of a four-group, five-lens configuration." Appx2378. And U.S. Patent No. 5,546,236 (Ogata), issued in 1996, describes "[a] wide-angle photographic lens system." Appx3645.

Neither the Kawamura nor Ogata lens systems were specifically designed for use in a standalone digital camera like that disclosed in Parulski. *See* Appx3658 (3:5-6); Appx2378. But as the seminal publication *Modern Lens Design* by Warren J. Smith (hereinafter

"Smith") explains, "[a] lens prescription can be scaled to any desired focal length simply by multiplying all of its dimensions by the same constant." Appx2678. The user manual for Zemax—"a program which can model, analyze, and assist in the design of optical systems"—confirms as much. Appx3014 (discussing "scaling an existing [lens] design to a new focal length").

When scaling a lens, linear measures—like lens radius—are all "scaled by the same factor." Appx2678 (Smith); Appx3014 (Zemax: "If the scale factor is X, then data measured in lens units of length with be scaled by the factor X."). However, "angular characteristics"—like the field of view and f-number (*see supra* at 5, 14 n.3)— "remain completely unchanged by scaling." Appx2678 (Smith); Appx3014 (Zemax: "dimensionless" parameters are "not scaled"). And "[s]ome polynomial coefficients, such as those on the Even Aspheric surface, have units that change from term to term" rather than scaling by X or remaining constant; scaling software like Zemax "accounts for this when scaling the data." Appx3014.

Because Parulski does not specify prescription data or an image sensor size for its camera, one must look to comparable dual-lens digital

cameras from the same era—like the Kodak EasyShare V610 dual lens digital camera, referenced as prior art in Parulski, Appx1986 (5:29-30)—to determine what size "image sensors that Parulski would have considered for use in its camera." Appx2718. The V610 camera had two 1/2.5" image sensors. Appx3782. Thus, scaling the Kawamura and Ogata lenses to accommodate 1/2.5" image sensors would allow those lenses to be used in Parulski's camera. Appx2718-2719; Appx2722-2723; Appx2731-2736. This would require scaling Ogata by a factor of 6.114. Appx4798. Focal length would go from 35mm to 5.72mm, and the f-number (2.9) and field of view (63.4 degrees) would remain the same. Appx2718-2719. Kawamura would be scaled by a factor of 12.25. Appx4789. Focal length would go from 200mm to 16.33mm, while the f-number (4.0) and field of view (24.3 degrees) would remain the same. Appx2723.

The '479 patent claims a dual-aperture camera unit that outputs a combined image.

Similar to the prior art, U.S. Patent No. 10,225,479 (the '479 patent), discloses "a thin (*e.g.*, fitting in a cell-phone) dual-aperture

zoom digital camera with fixed focal length lenses" configured to output a "fused image." Appx65 (3:18-23, 36-37, 47-48).

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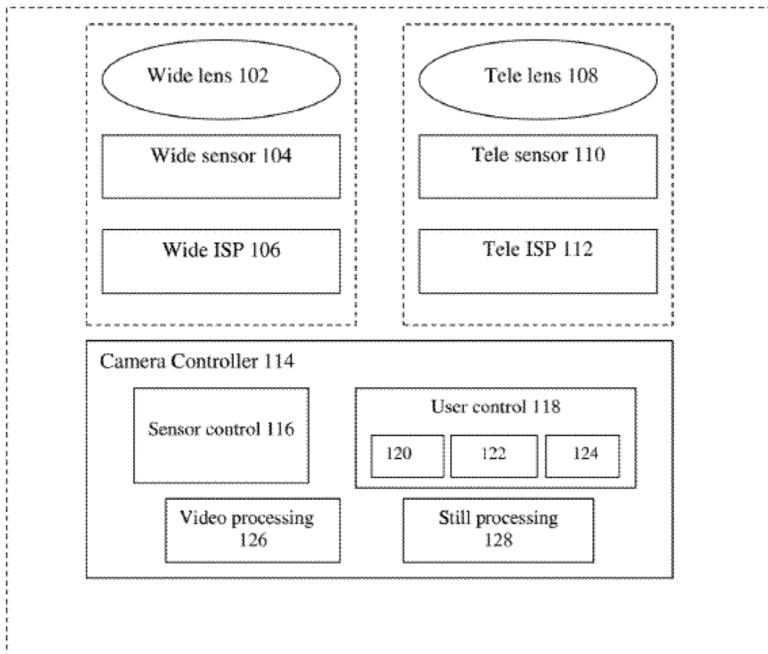

FIG. 1A

Appx56.

As a dual-aperture camera, the invention claimed in the '479 patent contains "two sub-cameras, a Wide sub-camera and a Tele sub-camera," where "[t]he Tele sub-camera is the higher zoom sub-camera and the Wide sub-camera is the lower zoom sub-camera." Appx65 (3:37-41). The camera "can be operated in both still and video modes"; "[i]n still mode," at issue here, "zoom is achieved 'with fusion' (full or partial), by fusing W[ide] and T[ele] images, with the resulting fused image

including always information from both W[ide] and T[ele] images." Appx65 (3:47-51).

As relevant to this appeal, a fused image will take on a point of view from one or both images. As previously discussed, there are two types of point of view: shape (also called perspective) and position. *See supra* at 8-9; *see also* Appx66 (5:10-13) ("[A]s seen by each sub-camera … a given object will be shifted and have different perspective (shape)."). According to the '479 patent, "[t]he system output image can have the shape and position of either sub-camera image or the shape or position of a combination thereof." Appx66 (5:13-15). "If the output image retains the Wide image shape then it has the Wide perspective POV. If it retains the Wide camera position then it has the Wide position POV. The same applies for Tele images position and perspective." Appx66 (5:15-20).

Two image-processing techniques claimed by the '479 patent are at issue in this case. First, the camera unit described above may be configured "to output the fused image with a point of view (POV) of the Wide camera by mapping Tele image pixels to matching pixels within

the Wide image." Appx70 (13:40-50) (claims 1 and 23). This technique results in a fused output image having a broader depth of field.

Second, the camera unit described above may be "configured … to process the Wide and Tele images to find translations between matching points in the images to calculate depth information and to create a fused image suited for portrait photos, the fused image having a DOF [depth of field] shallower than DOF_T [depth of field of the Tele camera], and having a blurred background." Appx71 (15:27-33) (claim 19). This technique results in a fused output image with a narrowed depth of field where the subject of the image is in focus and the background is blurred, thereby creating a bokeh effect. In fact, some embodiments describe the fused output image "as a portrait photo similar to a portrait photo taken with a digital single-lens reflex (DSLR) camera." Appx71 (15:43-46) (claim 21); Appx71 (15:47-48) (claim 22). In other embodiments, a particular lens design is used. Appx71 (claim 20).

Apple files two petitions for inter partes review.

In 2019, Corephotonics filed suit against Apple, alleging infringement of ten patents, including the '479 patent. *Corephotonics,*

Ltd. v. Apple Inc., No. 3:19-cv-04809 (N.D. Cal.). In response, Apple filed two petitions for inter partes review. The first, IPR2020-00905 (the -905 IPR), concerned the camera disclosed in independent claims 1 and 23 of the '479 patent, configured to create a fused image with a point of view of the Wide sub-camera. The second, IPR-2020-00906 (the -906 IPR), concerned the camera disclosed in independent claim 19 of the '479 patent, configured to create a fused image with a shallow depth of field and blurry background.

The Board instituted review of both petitions.

In the -905 IPR, the Board rejects Apple's claim construction and, on that basis, finds Apple failed to carry its burden to prove unpatentability.

In the -905 IPR petition, Apple demonstrated that the combination of Parulski and Konno—when combined with one or more additional prior-art references—rendered claims 1-16, 18, 23-38, and 40 unpatentable as obvious. As relevant here, Apple argued that Parulski teaches a dual-aperture camera with Wide and Tele lenses operative to generate "a fused image with a point of view (POV) of the Wide camera."

The petition identified only one claim term requiring construction: "fused image with a point of view (POV) of the Wide camera." Appx91. As is explained above, the output image of the claimed invention can have the Wide perspective/shape or the Wide position (or neither, or both). *See supra* at 19; Appx66 (5:13-15) ("The system output image can have the shape and position of either sub-camera image *or the shape or position of a combination thereof*." (emphasis added)). Because the specification describes Wide POV in two alternative ways and does not specify that a certain type of POV must be maintained by image fusion, Apple construed the term "fused image with a point of view (POV) of the Wide camera" to mean a "fused image in which the positions *or* shapes of objects reflect those of the Wide camera." Appx349 (emphasis added); Appx10.

Apple explained how Parulski rendered independent claims 1 and 23 obvious. With respect to "output[ting] the fused image with the point of view (POV) of the wide camera," Apple explained that "Parulski teaches an image enhancement process where in-focus portions of the telephoto image are combined with the wide image to broaden the wide image's depth of field." Appx113. A person of ordinary skill "would

have understood" that this process, by its very nature, "would have otherwise maintained the wide image," therefore outputting a fused image that reflects the scene as viewed by the wide camera. Appx113. And with respect to "mapping Telephoto image pixels to matching pixels within the Wide image," Apple explained that "Parulski's range map is generated by matching pixels from the telephoto image to matching pixels in the wide image," satisfying the limitation. Appx114.

Corephotonics did not dispute Apple's construction in its preliminary response, contesting instead whether Parulski teaches the creation of a "fused image." Appx179-182. The Board, finding no claim construction necessary "to determine the merits of the Petition," declined to adopt one in its institution decision. Appx207.

In its Patent Owner response, Corephotonics for the first time urged a different construction of the claim term: "fused image in which the positions *and* shapes of objects reflect the POV of the Wide camera." Appx270 (emphasis added). Still, Corephotonics did not advance any argument that Parulski's technique for combining sub-camera images does not maintain Wide position and shape such that it would lack the Wide POV under Corephotonics's construction (indeed, it later conceded

it does). Appx286-288; *infra* at 54-55. Instead, Corephotonics repeated its argument that Parulski does not teach output of a "fused image" at all, disclaiming that Parulski teaches any technique for "transferring image data from the secondary still image into the output image." Appx282-286.

In its Final Written Decision, the Board noted that the patent was "not a model of clarity." Appx11. It nonetheless adopted Corephotonics's claim construction, Appx11, construing the claim language to mean "a fused image having a Wide perspective POV *and* a Wide position POV." Appx12 (emphasis added).

The Board went on to find that Apple had not carried its burden to prove that claims 1 and 23 were unpatentable as obvious. According to the Board, because Apple had only argued that Parulski teaches "generating a fused image having a Wide position POV," it had "fail[ed] to demonstrate how Parulski's image fusion method would also maintain the Wide perspective POV." Appx21. And because the remaining claims all depended directly or indirectly on claims 1 and 23, the Board determined that Apple had failed to prove these claims were unpatentable as well. Appx21-22.

In the -906 IPR, the Board seized on a data-entry error by Apple's expert to find Apple failed to carry its burden to prove unpatentability.

In the -906 petition, Apple demonstrated that the combination of Parulski, Kawamura, Ogata, and additional prior-art references rendered claims 19-22 of the '479 patent unpatentable as obvious. As relevant here, Apple argued that a person of skill would have been motivated to scale down the Kawamura and Ogata lenses for use in Parulski's camera, and the resulting camera system would satisfy all limitations of claims 19-22.

Citing the Smith textbook on lens design, Apple explained that "[a] lens prescription can be scaled to any desired focal length simply by multiplying all of its dimensions by the same constant." Appx2678. Apple's expert Dr. José Sasián—a tenured professor of Optical Sciences at the University of Arizona—used the Zemax program to demonstrate how the Kawamura and Ogata lenses could be scaled for Parulski. *See* Appx2718-2719; Appx2731-2733; *supra* at 16-17. He determined that a person of ordinary skill would have used a 1/2.5" image sensor in Parulski's digital camera embodiment. *See supra* at 17; Appx2718-2719; Appx2731-2733; *see also* Appx4780-4781 (Corephotonics's expert

Dr. Moore agreeing with use of 1/2.5" image sensor in scaling analysis). Dr. Sasián's Zemax calculations showed that, to accommodate a 1/2.5" image sensor, the Ogata lens would have to be scaled by a factor of about 6 and the Kawamura lens would have to be scaled by a factor of about 12. *See supra* at 17. The focal length of the lenses would be reduced by those factors, but the f-number and field of view of the lenses would remain the same. *Id.*

When entering the Ogata lens data into Zemax to conduct the scaling analysis, Dr. Sasián made a data-entry error: "For the third lens element he mistakenly [entered] an Abbe number of 26.5 (the Abbe number of the second lens element), rather than the value 42.72 given in Ogata." Appx4798; *see also* Appx2733, Appx3660 (7:45). (Recall that the Abbe number reflects the material from which a lens is made, which affects refraction. *See supra* at 14 & n.2.) Comparing Ogata's prescription data to Dr. Sasián's Figure 3C illustrates the mistake:

Embodiment 1

$f = 35.0$, $f_B = 26.1$, F/2.9, $2\omega = 63.4°$

$r_1 = 14.1000$			
	$d_1 = 3.700$	$n_1 = 1.79952$	$\nu_1 = 42.24$
$r_2 = 47.5750$			
	$d_2 = 1.800$		
$r_3 = -81.2140$			
	$d_3 = 1.000$	$n_2 = 1.76182$	$\nu_2 = 26.52$
$r_4 = 12.0220$ (aspherical surface)			
	$d_4 = 1.000$		
$r_5 = 55.8920$			
	$d_5 = 3.000$	$n_3 = 1.83481$	$\boxed{\nu_3 = 42.72}$
$r_6 = -11.3420$			
	$d_6 = 1.000$	$n_4 = 1.53172$	$\nu_4 = 48.90$
$r_7 = -106.9860$			
	$d_7 = 1.000$		
$r_8 = \infty$ (stop)			
	$d_8 = 2.000$		
$r_9 = -10.4990$			
	$d_9 = 1.500$	$n_5 = 1.51633$	$\nu_5 = 64.15$
$r_{10} = -9.0360$ (aspherical surface)			

Appx3660 (7:45) (Ogata prescription data) (emphasis added).

3. *Fig. 3C – Prescription Data*

Lens Data Editor

Edit Solves View Help

Surf	Type	Comment	Radius	Thickness	Glass	Semi-Diameter	Conic	Par
OBJ	Standard		Infinity	Infinity		Infinity	0.000000000	
1*	Standard		2.306209846	0.605175633	1.80,42.2	1.308487856 U	0.000000000	
2*	Standard		7.781413719	0.294409768		1.144926874 U	0.000000000	
3*	Standard		-13.2834416	0.163560982	1.76,26.5	0.940475647 U	0.000000000	
4*	Even Asph..		1.966330126	0.163560982		0.830000000 U	0.039600000	
5*	Standard		9.141750406	0.490682946	1.83,26.5	0.900000000 U	0.000000000	
6*	Standard		-1.85510866	0.163560982	1.53,48.9	0.900000000 U	0.000000000	
7*	Standard		-17.4987352	0.163560982		0.858695155 U	0.000000000	
STO	Standard		Infinity	0.327121964		0.778746435	0.000000000	
9	Standard		-1.71722675	0.245341473	1.52,64.2	0.852109096	0.000000000	
10	Even Asph..		-1.47793703	4.274573517 M		0.936989741	0.303700000	
IMA	Standard		Infinity	-		3.569545975	0.000000000	

Appx2733 (Dr. Sasián's Zemax results) (emphasis added).

Corephotonics pointed out this error in its Patent Owner response. Appx932. It did not, however, claim that entering the wrong Abbe

number, associated with a different lens material, would affect any of the relevant data from Dr. Sasián's scaling analysis discussed in the body of his declaration, such as the focal length, f-number, or field of view. Instead, according to Corephotonics's expert Dr. Moore, the effect of the Abbe number error would have been limited to the calculations for "field curvature, distortion and OPD fan plots," depicted in Figure 3B in the Appendix to Dr. Sasián's report. Appx4798. Moreover, the issue of Dr. Sasián's mistake came up only as an aside in the background section of Corephotonics's brief. Appx932. It was not mentioned in Corephotonics's argument on obviousness.

Instead, Corephotonics argued that a person of ordinary skill looking for lenses to use in Parulski's camera "would have looked to lenses designed for miniature digital camera modules, not to 15- and 25-year-old lenses, many times larger than desired, designed and built using old technology, intended for use in film cameras." Appx940. According to Corephotonics, "[s]caling a design can dramatically alter the practicality of manufacturing the design and its sensitivity to variations in manufacturing," and some "performance characteristics for judging a lens design … change with the scale of a lens." Appx942.

In Corephotonics's expert's opinion, "scaling a good conventional lens design to a smaller size will often produce a design that is substantially inferior for its intended purpose to designs that were specifically created to be used as small lenses. Appx4803. According to Corephotonics, "the difficulties of scaling conventional lenses to miniature size" would have stopped a person of ordinary skill from scaling down Kawamura and Ogata. Appx943.

In reply, Apple explained that the premise of Corephotonics's argument was wrong: A camera with a 1/2.5" image sensor is not a miniature camera at all. Appx1027-1028. Thus, the sources cited in Corephotonics's Patent Owner Response detailing supposed problems with scaling conventional lenses down to miniature size, *see, e.g.*, Appx943-946, were inapplicable to scaling Kawamura and Ogata for use in Parulski.

In its final written decision, the Board sidestepped the crux of the disagreement between the parties about whether a person of ordinary skill would have selected a different lens design than Kawamura and Ogata due to the difficulties in scaling down conventional lenses to miniature size. Instead, it seized on Dr. Sasián's Abbe number data-

entry mistake. Appx39. The Board also purported to identify, *sua sponte*, other supposed errors in Dr. Sasián's scaling analysis. Appx37, Appx41 n.10. Despite the fact that even Corephotonics did not cite any Zemax error as material to the obviousness inquiry, the Board found this issue outcome-determinative. According to the Board, Apple's argument about scaling lenses was "entirely based on Dr. Sasián's opinion, which [wa]s based on Dr. Sasián's Zemax lens design software analysis." Appx40. Finding Dr. Sasián's analysis unreliable, the Board determined that Apple failed to demonstrate nonobviousness. Appx40.

This appeal followed.

SUMMARY OF ARGUMENT

I. The Board erred in both the -905 IPR and the -906 IPR. In the -905 IPR, the Board adopted an erroneous construction of the term "fused image with a point of view of the Wide camera." Although nothing in the claim limits "a point of view of the Wide camera" to an image with both Wide position *and* Wide shape point of view, the Board limited the claim in that way. That interpretation ignored the specification's use of "point of view" to mean either position *or* shape *or* both, and it and improperly limited the claims to one preferred

embodiment. Under the correct construction of the term, Corephotonics makes no serious argument that Parulski does not teach this limitation. And even under the Board's construction, Corephotonics made a key concession in its sur-reply effectively conceding that Parulski meets even Corephotonics's cramped construction.

II. In the -906 IPR, the Board made up its own basis for finding the claims not unpatentable. Instead of resolving the dispute between the parties, the Board seized on an inconsequential data-entry error by Apple's expert. That error had no bearing on the obviousness question, and Corephotonics never argued that it did. By *sua sponte* elevating a minor mistake into a case-dispositive issue, the Board ran afoul of the Administrative Procedure Act, and its decision is separately unsupported by substantial evidence.

STANDARD OF REVIEW

This Court reviews decisions of the Board under the Administrative Procedure Act (APA). *E.g., Pers. Web Techs., LLC v. Apple, Inc.*, 848 F.3d 987, 992 (Fed. Cir. 2017). The Board's legal conclusions are reviewed de novo. *ESIP Series 2, LLC v. Puzhen Life USA, LLC*, 958 F.3d 1378, 1383 (Fed. Cir. 2020). The Board's claim

construction, when based upon intrinsic evidence, is a matter of law reviewed de novo. *Seabed Geosolutions (US) Inc. v. Magseis FF LLC*, 8 F.4th 1285, 1287 (Fed. Cir. 2021) (vacating and remanding based on claim construction error).

The Board's factual findings, including its findings on motivation to combine, are reviewed for substantial evidence. *TQ Delta, LLC v. Cisco Sys., Inc.*, 942 F.3d 1352, 1357 (Fed. Cir. 2019) (reversing motivation to combine findings). However, the Board violates the APA if it "fail[s] to adequately evaluate [a party's] primary argument," *Power Integrations, Inc. v. Lee*, 797 F.3d 1318, 1325 (Fed. Cir. 2015), or "fail[s] to make a [relevant] factual finding," *VirnetX Inc. v. Cisco Sys., Inc.*, 776 F. App'x 698, 703 (Fed. Cir. 2019). It also violates the APA if it rules on a ground of which the parties were not given notice or an opportunity to respond. *See In re IPR Licensing, Inc.*, 942 F.3d 1363, 1368-69 (Fed. Cir. 2019); *Nike, Inc. v. Adidas AG*, 955 F.3d 45, 53 (Fed. Cir. 2020). In these circumstances, "the appropriate course of action" is "to vacate and remand the findings for further consideration." *Google LLC v. Conversant Wireless Licensing S.A.R.L.*, 753 F. App'x 890, 895 (Fed. Cir. 2018).

ARGUMENT

"A patent for a claimed invention may not be obtained … if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art to which the claimed invention pertains." 35 U.S.C. § 103. Evaluating the legal question of obviousness requires "underlying factual determinations" on the so-called *Graham* factors, which include "(1) the scope and content of prior art; (2) differences between prior art and claims; (3) the level of ordinary skill in the art; and (4) objective indicia of nonobviousness." *PAR Pharm., Inc. v. TWI Pharms., Inc.*, 773 F.3d 1186, 1193 (Fed. Cir. 2014) (citing *Graham v. John Deere Co.*, 383 U.S. 1, 17-18 (1966)).

"[W]here, as here, all claim limitations are found in a number of prior art references," the question is whether "a skilled artisan would have been motivated to combine the teachings of the prior art references to achieve the claimed invention, and [whether] the skilled artisan would have had a reasonable expectation of success in doing so." *Pfizer, Inc. v. Apotex, Inc.*, 480 F.3d 1348, 1361 (Fed. Cir. 2007). "[A]

motivation to combine can be found explicitly or implicitly in the prior art references themselves, in market forces, in design incentives, or in 'any need or problem known in the field of endeavor at the time of invention and addressed by the patent.'" *Arctic Cat Inc. v. Bombardier Recreational Prods. Inc.*, 876 F.3d 1350, 1359 (Fed. Cir. 2017) (quoting *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 420 (2007)).

I. In The -905 IPR, The Board Erred In Construing The Claim Term "Fused Image With A Point Of View Of The Wide Camera," And Thus Wrongly Found Parulski Did Not Teach The Claim Limitation.

Claims 1 and 23 recite that the camera outputs a "fused image with a point of view (POV) of the Wide camera." Appx70-71 (13:47-48, 15:65-66). The term "point of view" can refer to two characteristics of an image: position or perspective. *Supra* at 8-10. In the -905 IPR, the Board construed the claim term "fused image with a point of view of the Wide camera" to require the image to have *both* Wide position *and* Wide perspective. Appx12 ("[W]e construe a fused image having a Wide POV to mean 'a fused image having a Wide perspective POV and a Wide position POV.'"). On that basis the Board found that Parulski does not teach the final limitation of Claims 1 and 23.

The Board's claim construction was error. The two POV options taught in the patent are disjunctive, not conjunctive. Accordingly, the claim term "fused image with a point of view of the Wide camera" means "a fused image having *either* a Wide perspective *or* a Wide position POV." § I.A. The Board erred in concluding otherwise. § I.B. Under the correct construction, Parulski teaches this limitation (and Corephotonics scarcely contends otherwise). § I.C.1. Even under the Board's construction, however, Corephotonics conceded that Parulski teaches that the fused image has a point of view of the Wide camera. § I.C.2. The Board's decision on the -905 IPR should be reversed.

A. The claim term "fused image with a point of view of the Wide camera" means *either* Wide camera position *or* Wide camera perspective.

The claim language and specification both make clear that a "fused image with a point of view of the Wide camera" means a fused image with either the Wide shape POV or the Wide position POV.

Beginning with the claim language itself, claim 1 requires:

> e) a camera controller operatively coupled to the first and second AF mechanisms and to the Wide and Tele image sensors and configured to control the AF mechanisms and to process the Wide and Tele images to create a fused image, wherein areas in the Tele image that are not focused are not combined with the Wide image to create the fused image and

> wherein the camera controller is further operative to output the *fused image with a point of view (POV) of the Wide camera* by mapping Tele image pixels to matching pixels within the Wide image.

Appx70 (13:40-50) (emphasis added). The claim refers to "a point of view (POV) of the Wide camera," not a Wide position or Wide perspective point of view, and the claim says nothing suggesting the point of view is *solely* from the Wide camera. The dependent claims also do not further specify Wide perspective or Wide position point of view, suggesting that the claim language includes either one. *See Scanner Techs. Corp. v. ICOS Vision Sys. Corp., N.V.*, 365 F.3d 1299, 1304-05 (Fed. Cir. 2004) (construing "an illumination apparatus" to include multiple illumination sources in the absence of narrowing language in other claim limitations).

Turning to the specification, the '479 patent contemplates *multiple* iterations of Wide POV. It gives different examples of Wide POVs: "If the output image retains the Wide image shape then it has the Wide perspective [*i.e.*, shape] POV," and if the output image "retains the Wide camera position then it has the Wide position POV." Appx66 (5:15-19). The specification further explains that "[t]he system output image can

have the shape and position of either sub-camera image *or the shape or position of a combination thereof*." Appx66 (5:13-15) (emphasis added).

Claim 1's nonspecific "a point of view (POV) of the Wide camera" is best read to encompass any of these Wide POVs described in the specification: Wide position POV, Wide perspective POV, or both.

That is the lesson of *Immunex Corp. v. Sanofi-Aventis U.S. LLC*, 977 F.3d 1212 (Fed. Cir. 2020). *Immunex* involved a dispute over the proper construction of the claim term "human antibody." As the patent specification there explained, an antibody developed for therapeutic purposes "may be partially human, or … completely human." *Id.* at 1219. The patent included no "express definition" of the non-specific term "human antibody," but the patentee insisted that the term should be construed to mean *only* "completely human" antibodies. *Id.* at 1218. The Court rejected that view. Instead, finding "nothing in the claim's language restrict[ing] 'human antibodies' to those that are fully human," the Court held that it should be construed as "a broad category encompassing *both* partially and completely human antibodies," as the

term was used in the specification. *Id.* at 1218-19 (emphasis added).[4] The same logic applies here, hence the correct construction: a "fused image in which the positions *or* shapes of objects reflect those of the Wide camera."

Two distinct embodiments of the invention detailed in the specification further confirm the correct claim construction. The claim requires "a point of view (POV) of the Wide camera," which is achieved "by mapping Tele image pixels to matching pixels within the Wide image." Appx70 (13:48-50). The specification gives a few examples of mapping Tele image pixels to the Wide image. First, the specification states that the camera may "register Tele image pixels to a matching pixel set within the Wide image pixels." Appx66 (5:24-26). The specification describes the resulting image as one with "Wide POV" generally, without expressly stating whether it has Wide position, Wide perspective, or both. Appx66 (5:26). A few sentences later, however, the specification makes clear that the foregoing example (registering

[4] Although the Court in *Immunex* used the "broadest reasonable interpretation" standard, *id.* at 1217, it noted that no party had suggested the case would come out differently under the *Phillips* standard, *id.* at 1217 n.3.

Tele pixels to the Wide image) retains only Wide position POV and *not* Wide perspective POV. This is because, the specification clarifies, an additional preceding step must be performed if the user wishes to also retain the Wide shape point of view. Appx66 (5:30-34). In that preceding step, the Tele image must first be "shifted," and only thereafter is the pixel-matching "registration" performed. *Id.* Without this additional step, a registration map maintains only Wide position POV, and so does the resulting fused image. *See* Appx3910-3911. The specification nonetheless describes the first embodiment—an image maintaining only Wide position POV—as "retain[ing] the Wide POV." Appx66 (5:26). Thus, if no pre-registration "shifting" operation occurs before "mapping Tele image pixels to matching pixels within the Wide image," as required by claim 1, Appx70 (13:49-50), the output image retains just the Wide position POV. The claim itself does not *require* shifting—that is just one of two possible embodiments disclosed; the specification also describes an embodiment that does not involve shifting. Apple's proposed construction properly allows for both of these examples to fall within claim 1. *Cf. Immunex*, 977 F.3d at 1220.

In sum, the claim language, the specification's descriptions of POV, and the embodiments of pixel-mapping all point in the same direction: A "point of view (POV) of the Wide camera" signifies that "positions *or* shapes of objects reflect those of the Wide camera."[5]

B. The Board's claim construction is contrary to the claim language and specification, and imports limitations from a dependent claim.

In adopting Corephotonics's claim construction, the Board ignored key aspects of the claim language and specification. For starters, although the Board recognized that the '479 patent refers to more than one Wide POV, such as "Wide perspective POV" and "Wide position POV," it reasoned that "the position *and* perspective (shape) of an object in an image depends on the POV of the camera." Appx11. From that, it somehow discerned that Wide POV must entail both. That is classic converse fallacy, and does not follow from the Board's premise. Certainly, if both the position and shape of objects in an image are those of the Wide camera, the image has a Wide POV. But the converse isn't necessarily true.

[5] There is no relevant prosecution history for the term "fused image with a point of view of the Wide camera."

Moreover, the Board's statement on this front ignores the image processing steps required by the claims. When capturing an image in the first instance, position and shape do travel together: The Wide camera is going to capture an image with the Wide position and the Wide shape. But the whole point of the patent is to create a *fused* image, and that fused image "can have the shape and position of either sub-camera image *or the shape or position of a combination thereof.*" Appx66 (5:13-15) (emphasis added). So with the *fused* image, position and shape do not necessarily go together. That is precisely what gives rise to the parties' dispute.

When it finally considered the point of view of the fused image, the Board's reasoning was entirely conclusory. It began by listing some of the iterations, or combinations, of POV contemplated in the specification. *See* Appx11 (citing Appx66 (5:20-23). For example, it explained that an image with a Wide perspective POV could have the Wide position POV or the Tele position POV. Appx11. From there, the Board concluded, "a fused image has a Wide POV when it has both a Wide perspective POV and a Wide position POV." Appx11-12. Why? Because "[i]f the fused image did not have a Wide position POV it could

only be described as having a Wide perspective POV, not a Wide POV." Appx12.

That "reasoning" is no more than ipse dixit. It ignores that claim 1 entirely omits perspective or shape. And it ignores that the patent nowhere defines "Wide POV" *against* Wide perspective POV or Wide position POV, instead using "Wide POV" as an umbrella category that may include either.

Moreover, it impermissibly ignores the specification's description of an embodiment maintaining only Wide position POV as still "retain[ing] the Wide POV." Appx66 (5:26); *see also supra* at 38-39. "[T]here is a strong presumption against a claim construction that excludes a disclosed embodiment." *Immunex*, 977 F.3d at 1220 (quoting *Nobel Biocare Servs. AG v. Instradent USA, Inc.*, 903 F.3d 1365, 1381 (Fed. Cir. 2018)). If Wide POV is construed to require retaining both the position *and* shape of the Wide camera, then the un-shifted pixel-mapping embodiment expressly detailed in the specification would not satisfy the claim limitation, despite there being no indication that the term "Wide POV" is intended to exclude that embodiment. *See Nobel Biocare Servs.*, 903 F.3d at 1381 (rejecting claim construction that

excludes a disclosed embodiment where "the claim language does not require the exclusion").

As the last step of its flawed analysis, the Board pointed to Figure 5 of the '479 patent. Appx12. Figure 5 shows a series of image processing steps. Each step in the Figure 5 flowchart is recited in a different claim (or claims) of the '479 patent. For example, the second box (**504**) corresponds to claim 2, while the fifth box (**510**) corresponds to claims 5 and 6. *Compare* Appx60 (Figure 5), and Appx68 (9:39-60) (discussing Figure 5), *with* Appx70 (13:22-14:4) (claims 2 through 6). In general, Figure 5 describes the method for generating a "zoom image in still mode," Appx68 (9:40), and includes a "decision" step (**510**) before the final "fusion" step (**512**) in which "Wide pixel values are chosen to be used in the output image" whenever a comparison of the processed image data "detects significant dissimilarities." Appx68 (9:56-58); *see also* Appx70 (14:1-4) (same language in claim 6).

The Board determined that the decision step in the Figure 5 flowchart supports Corephotonics's construction of "a Wide POV" requiring both Wide position and Wide perspective POV. Appx12; *see also* Appx583-584 (oral argument questions on decision step). The

Board's analysis is difficult to follow, in part because it largely consists of quoting the various boxes in the flowchart. But the chain of reasoning appears to be as follows: First, the Board concluded that, after completing the process described in Figure 5, "the fused image contains no information from the Tele image that differs from information from the Wide image"—in other words, it has both the Wide shape and Wide position. Appx12. From this fact, the Board concluded "Wide POV" *must* mean both Wide perspective and Wide position POV.

The Board's reliance on Figure 5 is deeply flawed. To begin, the Board's analysis of decision step **510** rests on claim limitations found in claims 5 and 6—not claim 1. *See* Appx68 (9:51-58) (decision step **510**); Appx70 (14:1-4) (claim 6, reciting a camera controller "configured to choose Wide pixel values to be used in the output image" wherever it detects an "error" in the registration map). Claim 1 cannot be understood to include the limitation disclosed in claims 5 and 6. To conclude otherwise would violate the principle of claim differentiation: "[T]he presence of a dependent claim that adds a particular limitation gives rise to a presumption that the limitation in question is not present in the independent claim." *Phillips v. AWH Corp.*, 415 F.3d 1303, 1315

(Fed. Cir. 2005). So claim 1 does not include the additional steps, depicted in the second through sixth boxes of Figure 5, on which the Board relied.

Relatedly, the Board's conclusion is essentially that claim 6 recites an image that necessarily preserves both Wide perspective and Wide position POV. That does not mean that *claim 1* discloses an image preserving both Wide perspective and Wide position POV. In fact, we know from the specification that it doesn't: The specification contemplates that an output image may have "the shape and position of *either* sub-camera image *or* the shape *or* position of a combination thereof." Appx66 (5:13-15) (emphasis added). Indeed, if the term "Wide POV" in claim 1 signified that objects in the fused image reflected in every instance the shape and position of the Wide camera, then Claim 6 would be "superfluous." *InterDigital Commc'ns, LLC v. Int'l Trade Comm'n*, 690 F.3d 1318, 1325 (Fed. Cir. 2012).

Moreover, the fact that Figure 5 leads to a fused image with both Wide shape and position POV does not determine the meaning of "a Wide POV" in the claim language. At best it is a preferred embodiment,

which cannot "limit[] in scope" the claim. *Altiris, Inc. v. Symantec Corp.*, 318 F.3d 1363, 1370 (Fed. Cir. 2003).

In sum, the Board provides no persuasive analysis in support of Corephotonics's claim construction. It ignores the specification and the embodiments described therein, and it wrongly imports limitations from other dependent claims. The correct construction—that "a wide POV" includes either a Wide perspective/shape POV or a Wide position POV—is consistent with the plain claim language, accords with the multiple embodiments recited in the specification, and does not import a limitation from a dependent claim.

C. Parulski teaches the fused image has a "point of view of the Wide camera" under either construction.

Because the Board "relied on its erroneous claim construction" to find claims 1 and 23 nonobvious, that determination should at least be vacated and remanded to Board. *Kaken Pharm. Co. v. Iancu*, 952 F.3d 1346, 1354-55 (Fed. Cir. 2020). But here the Court may go further and reverse the Board entirely, because "uncontested findings regarding [Parulski] render [the claims] obvious under the proper [construction]." *Praxair Distrib., Inc. v. Mallinckrodt Hosp. Prods. IP Ltd.*, 890 F.3d 1024, 1036-37 (Fed. Cir. 2018); *see also Carrum Techs., LLC v. Unified*

Patents, LLC, No. 20-2204, 2021 WL 3574209, at *7 (Fed. Cir. Aug. 13, 2021) (finding "[r]eversal is appropriate" in case with "only [one] permissible factual finding" under the proper claim construction).

No party disputes that Parulski teaches matching Tele sub-camera pixels to pixels in a Wide sub-camera image to create a range map. *See* Appx1993 (19:49-20:15); Appx283; Appx605-607. Parulski further teaches that the range map may be "used to enhance the depth of field of the primary [Wide sub-camera] image" by "us[ing]" "the secondary [Tele sub-camera] image … to sharpen portions of the [Wide] image." Appx1994 (22:37-45). Thereby, Wide and Tele sub-camera images are "combined into a modified image with a broadened depth of field." Appx1997 (28:47-55). At minimum, this discloses a method for creating a fused image with the Wide position POV—meeting the claim limitation under the proper construction. Corephotonics has recognized as much. *See infra* at 50.

Indeed, reversal would be appropriate even if this Court accepts the Board's claim construction. That is because according to Corephotonics, Parulski's pixel-matching process necessarily retains Wide perspective POV as well as Wide position POV.

Simply stated, Parulski renders Claims 1 and 23 obvious under either claim construction, and reversal of the Board's contrary holding is warranted.

1. Parulski teaches outputting a fused image that maintains a Wide POV.

Claims 1 and 23 of the '479 patent require generating the "fused image with a [Wide POV]" "by mapping Tele image pixels to matching pixels within the Wide image." Appx70 (13:47-50), Appx66 (5:23-26). Likewise, Parulski teaches outputting a fused image that maintains a wide position POV.

Step one of this process is capturing both wide and tele images from the wide and tele lenses, respectively. Appx1995 (23:33-43); *see also* Appx1993 (19:63-65). At step two, Parulski uses the two images to create a "range map." Appx1993 (19:51). Initially, the image from the Wide camera is "cropped and upsampled so that corresponding features in the two … images span the same number of pixels." Appx1993 (20:4-6). Then the Tele image "is correlated with the cropped and upsampled [Wide] image to determine the pixel offset" and to generate a "map." Appx1993 (20:9-15).

Second, this pixel-matching range map is used to create a "fused image." *See* Appx70 (13:47). Parulski teaches use of the range map "for a variety of purposes," including to "enable object extraction from an image by identifying the continuous boundaries of the object so that it can be segmented within the image." Appx1993 (20:51-59). It further contemplates using portions of the Tele image—presumably, extracted pixels from the Tele image—"positioned near the [Tele] focus distance" to "sharpen portions" of the Wide image. Appx1994 (22:40-43). That process is outlined in Figure 14, whereby the Tele image is "used to enhance the depth of field of the [Wide] image." Appx1994 (22:37-42). Altogether, this results in a "fused image," in which the Tele and Wide images are "combined into a modified image with a broadened depth of field." Appx1997 (28:52-53); *cf.* Appx65 (3:48-51) ('479 patent describing a "fused image" as one which "includ[es] information from both [Wide] and [Tele] images").

The fused image has "a [Wide POV]," Appx70 (13:48), because, at minimum, the output image resulting from Parulski's enhancement process maintains Wide position POV. *See supra* at 40 (claim construction). This is because Parulski teaches that image data from

the Tele image is used to “sharpen portions” of the Wide image, “enhanc[ing] the depth of field” of the latter, Appx1994 (22:37-42), but “otherwise maintain[ing] the wide image,” Appx1798. In other words, objects still reflect the position of the Wide sub-camera in the resulting fused image, because pixels from the Tele camera have been correlated to those within the Wide image, extracted, and fused with the Wide image to broaden the image’s depth of field.

When pressed at oral argument, Corephotonics conceded both that Parulski teaches a technique for creation of a “range map” through pixel matching, *see* Appx605 (36:20-21), Appx607 (38:14-21), and that a range map may be used to combine Tele and Wide image data, Appx607 (38:4-10) (“Parulski … teaches you can [use a range map] to extract an object like a person in the foreground [of a Tele image] and … paste it into the wide perspective.”); Appx622 (53:17-20) (“Parulski … teaches in the fused image a combination where it has the … wide position[] [and] the [T]ele perspective or [a] combination [of both].”).

Corephotonics disputed only whether a person of ordinary skill would know to put Parulski’s teachings together, arguing that Parulski did not precisely disclose use of a “range map” for the purpose of

creating a "combined" or fused image. *See, e.g.*, Appx283, Appx4289. That is wrong as a factual matter. But that argument fails, as a legal matter, under the rule that a prior art reference must be "analyzed as a whole." *Gen. Elec. Co. v. Raytheon Techs. Corp.*, 983 F.3d 1334, 1352 (Fed. Cir. 2020). To prevent "unduly dissect[ing] prior art references into collections of individual elements," this Court presumes a motivation to combine the elements of a claim "present together" in a single prior art reference. *Id.* Thus, a person of "ordinary creativity" would know to combine Parulski's compatible teachings to create a fused image from a range map. *KSR*, 550 U.S. at 421; *see also Bradium Techs. LLC v. Iancu*, 923 F.3d 1032, 1049 (Fed. Cir. 2019) ("A reference must be considered not only for what it expressly teaches, but also for what it fairly suggests.").

In any event, as Apple explained, Parulski does explicitly teach deploying a range map to enhance a Wide image's depth of field by fusing Tele and Wide image data. It explains: "In order to understand the use of a range map for purposes such as noted above [*e.g.*, object extraction], it is helpful to consider an example." Appx1994 (21:1-8). It then provides the example of a photographer faced with mountains in

the distant range, flowers in the mid-range, and a dog in the foreground. Appx1994 (21:9-13). Initially, the image results in the dog being "out of focus," because the image is taken in "landscape mode"—that is, from the Wide camera. Appx1994 (21:14-16). But the specification teaches "use of the range map" to adjust the "depth of field," such that the "dog is in focus, the mountains are in focus, and so are those great flowers." Appx1994 (21:7, 21:25-27). It also suggests use of the range map "to isolate" part of the image, such as the dog in the foreground, to "sharpen[]" that portion of the image in particular. Appx1994 (21:27-31). These improved images are produced by using the "range data," that is, pixels from both Wide and Tele images that have been correlated and matched to form the range map. Appx1994 (21:28).

Corephotonics's further argument that Parulski teaches using the range map in a way that does not *fuse* data from the different images, Appx284, is incorrect. Parulski explicitly teaches using the range map to extract objects from an image. Appx1993 (20:57-58). The only conceivable purpose for such extraction is to fuse the extracted object with the other image, as the specification goes on to discuss in the

Alaskan mountains example. Appx1994 (21:7-44). Corephotonics acknowledged as much. *See supra* at 50 (citing Appx607 (38:4-10)).

In summary, Parulski teaches at minimum a fused image with a Wide POV, in which the positions of objects reflect those of the Wide camera. Parulski thus renders Claims 1 and 23 obvious under the proper claim construction.

2. Even if this Court accepts Corephotonics's claim construction, Parulski renders Claims 1 and 23 obvious.

The Board determined that Apple's "only argument for how the combination of Parulski and Konno teaches this limitation is Parulski's teaching of generating a fused image having a Wide position POV." Appx21. It thus declined to engage with the teachings of Parulski to consider whether Parulski teaches generating a fused image that "also maintain[s] the Wide perspective POV," as the Board's claim construction requires. Appx21. In so doing, the Board ignored a key concession Corephotonics made: To advance their claim construction argument, Corephotonics adopted a reading of the patent claims that Parulski undisputedly satisfies. The Court should reject Corephotonics's claim construction for the reasons stated above. *See*

supra at 35-46. If it adopts the conjunctive construction, however, its analysis necessarily requires a finding of obviousness, and the Court should hold Corephotonics to its concession. *See In re NTP, Inc.*, 654 F.3d 1279, 1305 (Fed. Cir. 2011) (finding a party is "bound by [its] concessions and may not reargue [those] points").

As discussed above, the '479 patent's specification discusses an embodiment wherein "register[ing] Tele image pixels to a matching pixel set within the Wide image pixel" results in an "output image [that] retain[s] the Wide POV." Appx66 (5:23-26). Corephotonics has urged that "Wide POV" means Wide position *and* perspective POV throughout the patent, including in that embodiment. *See* Appx270. Indeed, Corephotonics took the position in its sur-reply that "registering pixels to matching pixels"—as described in the relevant embodiment—"will *necessarily* address both position (shift) and perspective (shape)." Appx414. On that basis it urged the Board to read Wide POV as requiring Wide shape and position.

Yet at no point did Corephotonics dispute, or the Board question, that Parulski itself teaches the mapping of Tele image pixels to a matching pixel set within the Wide image, producing a range map. *See*

Appx1993 (20:1-15); Appx607 (38:20-21) (Corephotonics: "Pixel matching gives you a range map."); *supra* at 48. So if "registering pixels to matching pixels will *necessarily* address both position (shift) and perspective (shape)," Appx414 (emphasis added), as Corephotonics has contended, then Parulski plainly teaches this limitation. Thus, to the extent this Court accepts Corephotonics's reading of the claim language and specification, it must also hold Corephotonics to its concession, and determine that Parulski teaches this claim limitation, and thus that the claims are obvious.

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There is no way to construe the claim language that avoids finding Claims 1 and 23 obvious in view of Parulski. The Board's contrary finding should be reversed.

II. In the -906 IPR, The Board Violated The APA By Raising A New Argument *Sua Sponte* With No Notice, Requiring A Remand.

Apple established that a person of ordinary skill would scale the wide-angle lens of Ogata and the telephoto lens of Kawamura for use in Parulski's dual-lens digital camera. Dr. Sasián explained that the lens in both Ogata and Kawamura could be scaled for use in a camera with a

1/2.5" image sensor, and that a person of ordinary skill would have a reasonable expectation of success in doing so. Appx2718; Appx2722-2723.

As explained above, Dr. Sasián made a data-entry mistake when inputting the Ogata lens data into the Zemax lens design program. As Corephotonics itself recognized, "For the third lens element he mistakenly used an Abbe number of 26.5 (the Abbe number of the second lens element), rather than the value 42.72 given in Ogata." Appx4798; *see also supra* at 26-27. Inputting the wrong Abbe number had no impact on any datapoint from Dr. Sasián's analysis relevant to his scalability opinion, and even Corephotonics never argued that it was in any way material to the parties' dispute on obviousness. § II.A. But the Board, *sua sponte* and without notice to the parties, seized on Dr. Sasián's mistake to avoid resolving the parties' actual dispute on obviousness. In so doing, the Board violated the APA, requiring a remand regardless of the merits of the Board's *sua sponte* criticisms of Dr. Sasián's analysis. § II.B. Alternatively, the Board's findings are unsupported by substantial evidence, in which case a remand is also required. § II.C.

A. Apple shows that claims 19-22 are obvious, and while Corephotonics disputes aspects of Apple's showing, it never argues that Dr. Sasián's data-entry error has any bearing on obviousness.

Apple's petition demonstrated that claims 19-22 of the '479 patent are invalid as obvious. Claim 19 recites a digital camera with two lenses: one wide-angle and one telephoto. Appx70-71 (14:66-15:32). The camera controller can fuse images from each of the two lenses together "to create a fused image suited for portrait photos," commonly known as a bokeh effect. Appx71 (15:30-31). Apple's petition explained that Parulski taught a dual-lens digital camera with wide and tele lenses, plus a controller for creating a fused image. Appx739-740; Appx743-744.

Parulski did not teach the specific physical parameters of the wide and tele lenses. Appx749. Apple and its expert explained that, given Parulski's silence on the matter, a person of ordinary skill would look to other references for teaching the lens assemblies. Appx746-747; Appx2717-2718; Appx2722-2723. Apple relied on Ogata for teaching the wide lens, and Kawamura for teaching the tele lens. Appx746; Appx754. Both Ogata and Kawamura disclose using their lenses with larger cameras than those discussed in Parulski. *Id.* Citing a well-

known textbook on lens design, Apple and its expert explained that the Ogata and Kawamura lenses could nevertheless be scaled down for use in Parulski. Appx746-747, Appx750-751 (Kawamura); Appx753-754, Appx756-757 (Ogata). They further explained that combining Kawamura or Ogata with Parulski "would have been nothing more than using known methods to incorporate [the] lens assembly" into Parulski's dual-lens camera. Appx748-749; Appx755-756.

In response, Corephotonics argued that a person of ordinary skill would not have chosen to scale Kawamura or Ogata to use in Parulski. Appx940-946; *see also supra* at 28-29. In particular, Corephotonics claimed that it would be too difficult to manufacture a scaled-down Kawamura or Ogata lens: "[s]caling a design can dramatically alter the practicality of manufacturing the design and its sensitivity to variations in manufacturing." Appx942; Appx4802-4803. At bottom, Corephotonics claimed that a person of ordinary skill, instead of scaling down Kawamura and Ogata, "would have instead used a fully aspheric [lens] design with plastic elements"—features Kawamura and Ogata did not have but were, according to Corephotonics, required "to make an accepted *miniature* camera lens." Appx959 (emphasis added).

Corephotonics identified Dr. Sasián's data-entry mistake in a background section of its Patent Owner Response entitled "Overview of Selected Prior Art." Appx913; Appx932. The relevant paragraph began by stating that Dr. Sasián's Zemax analysis *confirmed* Corephotonics's expert's analysis on a different issue. Appx932 ("We can confirm this with Dr. Sasián's Zemax analysis."). As an "initial matter," Corephotonics noted that "Dr. Sasián appears to have made at least one error in entering the parameters from the Ogata Embodiment 1 lens." Appx932. Corephotonics asserted that inputting the wrong Abbe number meant that "Dr. Sasián's field curvature, distortion and OPD fan plots" in Figure 3B of the Appendix to his declaration "do not accurately reflect the performance of a scaled version of Ogata's Embodiment 1 lens." Appx932. Corephotonics did not cite any other lens parameters that would be affected by the mistake, nor did it argue that using the correct Abbe number would show Ogata's scaled lens unsuitable for Parulski. Indeed, the mistake was never mentioned again—not even in passing, and nowhere in the argument section of the Corephotonics's response.

In reply, Apple explained that Corephotonics's emphasis on the difficulties of scaling a conventional lens down to *miniature* size was misguided. While *miniature* cameras may be used in things like cellphones and tablets, the *claims* of the '479 patent did not require miniature cameras. Instead, claim 19 simply required "A dual-aperture digital camera," not a miniature camera—or even a camera for use in a cellphone. Miniature cameras suitable for a cellphone are in a distinct category from digital cameras with a 1/2.5" sensor, like the relevant embodiment of Parulski. *See* Appx3957-3958, Appx3961 (chart categorizing lens sizes); *see also* Appx3782 (technical specifications for Kodak EasyShare V610 dual lens digital camera, with 1/2.5" image sensors). Consequently, Apple explained, Corephotonics's argument about the problems in scaling Ogata down to *miniature* size are simply inapposite when considering scaling the Ogata lens down to accommodate a 1/2.5" image sensor. *See* Appx1029-1032.

The foregoing makes clear that Dr. Sasián's Abbe number mistake was simply immaterial to the parties' dispute about obviousness. Figure 3B in the Appendix to Dr. Sasián's declaration—the only data Corephotonics claimed would be affected by the mistake—does not

speak to the practicality and manufacturing concerns at the heart of Corephotonics's nonobviousness argument. Appx2732. The data therein—specifically "field curvature, distortion and OPD fan plots," Appx932—is not even mentioned in the body of Dr. Sasián's declaration as relevant to the scaling analysis Corephotonics was trying to refute. Appx2718. It is thus no surprise that neither party treated the issue as significant.

B. The Board's *sua sponte* reliance on Dr. Sasián's mistake to sidestep resolving the parties' actual dispute on obviousness violates the APA and requires a remand.

Notwithstanding the foregoing, the Board found Dr. Sasián's Abbe number mistake (along with non-existent mistakes discussed below) *dispositive*, and it was the sole basis for the Board's decision. *See* Appx39-41. This violates the APA in two related ways.

First, the APA generally requires "the Board [to] base its decision on arguments that were advanced by a party, and to which the opposing party was given a chance to respond." *IPR Licensing*, 942 F.3d at 1368-69. In limited circumstances the Board may raise issues *sua sponte*, but to do so it must "give[] the parties notice and an opportunity to respond." *Nike*, 955 F.3d at 53. These process requirements apply to

the Board's treatment of both petitioners and patent owners. *See SAS Inst., Inc. v. ComplementSoft, LLC.*, 825 F.3d 1341, 1351 (Fed. Cir. 2016), *rev'd and remanded on other grounds sub nom., SAS Inst., Inc. v. Iancu*, 138 S. Ct. 1348 (2018).

The Board ran afoul of those principles here. It based its decision solely on a data-entry mistake no party argued was material. *See supra* at 59-60. And it provided no advance notice to the parties of the contemplated basis for its decision. The Board's insistence that, once Corephotonics identified the mistake, Apple had an opportunity in its reply "to either correct its analysis or explain why the Abbe number discrepancy did not affect the analysis," actually highlights its error. Appx41. Corephotonics never argued that the Abbe number mistake was in any way material to the obviousness inquiry. Its identification of the mistake in passing in the background section of its brief did not put Apple on notice that the Board might *sua sponte* conclude that the mistake was material, and base its decision on the mistake instead of the obviousness arguments raised by the parties. If the Board thought the parties failed to appreciate the import of Dr. Sasián's mistake, the proper course of action was to provide the parties with notice of the

Board's concern, along with an opportunity to respond. *See*, *e.g.*, *Qualcomm Inc. v. Intel Corp.*, 6 F.4th 1256, 1263 (Fed. Cir. 2021) (the Board should have given notice to the parties before diverging from agreed-upon matter of claim construction); *Nike*, 955 F.3d at 53 (notice and an opportunity to respond are required for the Board to raise issues *sua sponte*). The Board did not do so. That failure requires a remand. *See Qualcomm*, 6 F.4th at 1262-63.

Second, the APA requires the Board to "provide an adequate ground" for its decisions. *Power Integrations*, 797 F.3d at 1325 (quoting *In re Thrift*, 298 F.3d 1357, 1366 (Fed. Cir. 2002)). This Court has explained that the Board fails to satisfy this obligation when it misapprehends or ignores the parties' arguments and instead "focuse[s] on a red herring." *See id.* (the Board spent "a significant portion of [its] opinion … rejecting an argument that [one party] not only never made, but instead expressly disavowed"). That is the case here. "Because so much"—indeed all—of the "[B]oard's analysis is focused on a red herring"— Dr. Sasián's data-entry mistake—"it failed to adequately evaluate" the actual dispute between the parties: whether a person of ordinary skill would have been motivated to scale Kawamura and

Ogata despite alleged practical concerns like manufacturing tolerances of scaled-down lenses, and instead chosen a more modern miniature lens design. *Id*. At best, the Board's decision is "incomplete" due to its "fail[ure] to address key arguments and issues properly before it." *Google*, 753 F. App'x at 895. "[T]he appropriate course of action" in this situation "is to vacate and remand the findings for further consideration.'" *Id.*; *see also Power Integrations*, 797 F.3d at 1325.

C. Alternatively, the dispositive weight the Board afforded Dr. Sasián's mistake is not supported by substantial evidence, also requiring a remand.

The Board's sole reliance on Dr. Sasián's mistake to hold claims 19-22 not unpatentable is unsupported by substantial evidence in two distinct ways. First, the Board was itself mistaken in characterizing as error certain aspects of Dr. Sasián's analysis *not* identified as such by Corephotonics. § II.B.1. The only true error was the Abbe number data-entry mistake Corephotonics identified, but the Board's conclusion that the error undermines Apple's obviousness argument is not supported by substantial evidence, as it has no basis in any expert testimony or record evidence. § II.B.2.

1. Some supposed errors identified by the Board were not errors at all.

Corephotonics identified only one error—the Abbe number mistake—in Dr. Sasián's Zemax analysis. Appx932. The Board, however, purported to find "[a] few" additional "inconsistencies" and "discrepancies" in that analysis. Appx39; Appx41 n.10. The Board was wrong. Its erroneous finding reveals a fundamental misunderstanding of the Zemax scaling analysis—a predictable result of a *sua sponte* scientific criticism unguided by adversarial presentation of the relevant scientific principles.

The additional discrepancies the Board identified all involved "aspherical surface[]" data. *See* Appx39 (claiming "the data for the fourth and tenth aspherical surfaces are noticeably different" between the Ogata prescription data and Dr. Sasián's Figure 3C). The Ogata aspherical surface coefficients are as follows:

aspherical surface coefficients	
(4th surface)	$P = 1.0396$, $A_4 = 0.66373 \times 10^{-4}$
	$A_6 = 0.13983 \times 10^{-5}$, $A_8 = -0.97157 \times 10^{-8}$
	$A_{10} = 0.42114 \times 10^{-9}$
(10th surface)	$P = 1.3037$, $A_4 = 0.44302 \times 10^{-4}$
	$A_6 = -0.17498 \times 10^{-5}$, $A_8 = 0.10177 \times 10^{-6}$
	$A_{10} = -0.17446 \times 10^{-8}$

Appx3660 (7:53-62).

Dr. Sasián's aspherical surface coefficients from his Figure 3C are below, with the data for the 4th aspheric surface on top and the data for the 10th aspheric surface on the bottom. What Dr. Sasián lists as "4th Order Term" is "A_4" in the Ogata prescription data, and so on.

2nd Order Term	4th Order Term	6th Order Term	8th Order Term	10th Order Term
0.000000000	0.015168838	0.011945431	-3.103E-003	5.0270E-003
0.000000000	0.010124748	-0.01494823	0.032498387	-0.02082469

Appx2733.

It is true that these numbers don't match. But they are not *supposed* to match. The Zemax manual specifically explains that the "polynomial coefficient[]" for "the Even Aspheric surface" "ha[s] units that change from term to term" rather than scaling by a factor of X or remaining constant; Zemax "accounts for this" automatically "when scaling the data." Appx3014.

Figure 3C contains the *scaled* data for the Ogata lens, meaning the *output* from Zemax. Appx2718-2719. Thus, the aspherical surface coefficients in Figure 3C should not be the same as the ones from

Ogata's embodiment 1, nor should they be scaled by a factor of 6. Appx3014. Instead, Zemax has already "accounted for" the appropriate scaling adjustment. That is why Corephotonics did not identify the aspherical surface coefficient variation between Ogata Embodiment 1 and Dr. Sasián's Figure 3C as an error—because it is not an error. The same is true with respect to the "inconsistency" the Board footnoted with respect to the Kawamura lens prescription data. *See* Appx41 n.10. The Board's contrary conclusion is not supported by substantial evidence.

Even if the Board had identified an error that Corephotonics missed—which it did not—any mistake with respect to the aspherical surface coefficients is immaterial for the reasons that follow.

2. Dr. Sasián's Abbe number mistake does not undermine Apple's showing of obviousness.

While the Abbe number mistake identified by Corephotonics is a genuine data-entry error, the Board was wrong to conclude the error fatally undermined Dr. Sasián's credibility or Apple's arguments on obviousness. No expert testimony or record evidence supports that result.

The Board justified its conclusion primarily on the ground that, in its view, Apple's scaling argument was "entirely based on Dr. Sasián's opinion, which is based on Dr. Sasián's lens design software analysis." Appx40. This is simply incorrect. Apple's petition is also "[b]ased on" and supported by Smith's *Modern Lens Design* textbook, which explains that "[a] lens prescription can be scaled to any desired focal length simply by multiplying all of its dimensions by the same constant." Appx753 (quoting Appx2678). Corephotonics never contested that Smith independently supports Apple's contention that Ogata's lens may scaled for use in Parulski's digital camera. In sum, Apple's scaling argument is *not* entirely based on Dr. Sasián's Zemax analysis, and so a data-entry error in that Zemax analysis does not undercut the entire argument.

That leads to the second error: The Board claimed that Dr. Sasián's error "call[s] into question Petitioner's contention that a person skilled in the art would have known that Ogata's lens could be scaled to work in Parulski's camera with a reasonable expectation of success." Appx40. To reiterate, Corephotonics never argued that Dr. Sasián's error cast any doubt whatsoever on Apple's argument that Ogata's lens

may be successfully scaled to fit Parulski. *See supra* at 59. The fact that lenses can be scaled is clear in prior art like Smith. *See supra* at 68. Corephotonics's argument was solely based on whether a person of ordinary skill would have expected that a scaled-down version of Ogata's lens would be manufacturable—which has nothing to do with Dr. Sasián's Zemax analysis.

A close look at that analysis reveals exactly that. Dr. Sasián concluded that Ogata "scaled for a 1/2.5" image sensor" "would have maintained the same field of view (FOV_w) of 63.4 degrees and f-number of 2.9 but would have had a lower focal length (EFL) of 5.82 mm and a total track length (TTL) of 6.892 mm as a result of the scaling." Appx754 (citing Appx2718). Corephotonics did not claim that a typographical error inputting the Abbe number would affect any of these numbers, nor did the Board. The lens properties ("field curvature, distortion and OPD fan plots") that Corephotonics claims are "not accurately reflect[ed]" in Figure 3B in the Appendix of Dr. Sasián's declaration due to the Abbe number mistake are mentioned *nowhere* in Apple's petition or Corephotonics's nonobviousness argument. *See, e.g.*, Appx753-755; *supra* at 59.

The only support the Board purports to identify for its conclusion that the mistake was material to Apple's argument is Dr. Moore's opinion "that '[a] significant change in the index of refraction or the Abbe number can change a highly performing lens design into an unacceptable design.'" Appx39 (quoting Appx4812). That statement in Dr. Moore's declaration has nothing to do with Dr. Sasián's mistake; indeed, it comes about 50 paragraphs after Dr. Moore identifies that mistake. What Dr. Moore is instead discussing in paragraph 88 of his declaration is using plastic instead of glass in a lens design: He opines that substituting one lens material for another in a given lens design can affect lens performance. Appx4811-4812. Of course, in his Zemax analysis, Dr. Sasián was not actually recommending altering the Ogata lens design to use a material with a different Abbe number. He simply made a mistake entering data into a spreadsheet. None of the data affected by that error was cited by either party as relevant to the viability or impossibility of scaling down Ogata's wide-angle lens for use in Parulski's digital camera. In sum, this paragraph of Moore's declaration is inapposite and does not support the Board's conclusion.

Finally, the Board tried to place blame on Apple, claiming that once Corephotonics identified Dr. Sasián's error, "the burden of production [shifted] to Petitioner to either correct its analysis or explain why the Abbe number discrepancy did not affect the analysis." Appx41 (citing *Dynamic Drinkware, LLC v. Nat'l Graphics, Inc.*, 800 F.3d 1375, 1379 (Fed. Cir. 2015)); *see also supra* at 62. The shifting burden of production described in *Dynamic Drinkware* is, at its core, about a party's obligation to respond to the other side's *argument*. 800 F.3d at 1379-80. As explained above, Corephotonics's arguments about obviousness had nothing to do with Dr. Sasián's mistake. *See supra* at 57-61. Apple responded at length to those arguments in its reply—meeting its burden of production on the material dispute between the parties. Appx1026-1036. It did not fail to meet its burden of production simply because its reply brief did not address Dr. Sasián's data-entry error, which neither party deemed consequential. So this factor, too, fails to support the Board's conclusion.

In sum, the Board's *sua sponte* conclusion that a single data-entry mistake fatally undermined Apple's obviousness argument is

unsupported by substantial evidence. A remand is required for the Board to resolve the parties' actual dispute.

CONCLUSION

For the foregoing reasons, this Court should reverse or remand the -905 IPR, and remand the -906 IPR.

Respectfully submitted,

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June 24, 2022

ADDENDUM

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Paper 51
Entered: November 8, 2021

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

APPLE, INC.,
Petitioner,

v.

COREPHOTONICS LTD.,
Patent Owner.

IPR2020-00905
Patent 10,225,479 B2

Before BRYAN F. MOORE, JOHN F. HORVATH, and MONICA S. ULLAGADDI, *Administrative Patent Judges.*

HORVATH, *Administrative Patent Judge*.

JUDGMENT
Final Written Decision
Determining No Challenged Claims Unpatentable
35 U.S.C. § 318(a)

I. INTRODUCTION

A. Background and Summary

Apple, Inc. ("Petitioner") filed a Petition requesting *inter partes* review of claims 1–16, 18, 23–38, and 40 ("the challenged claims") of U.S. Patent No. 10,225,479 B2 (Ex. 1001, "the '479 patent"). Paper 3 ("Pet."), 9. Corephotonics Ltd. ("Patent Owner") filed a Preliminary Response. Paper 8 ("Prelim. Resp."). Upon consideration of the Petition and Preliminary Response, we instituted *inter partes* review of all challenged claims on all grounds raised. Paper 10 ("Dec. Inst.").

Patent Owner filed confidential (Paper 15) and public (Paper 39) versions of its Response to the Petition. *See* Paper 39 ("PO Resp.").[1] Petitioner filed confidential (Paper 24) and public (Paper 40) versions of a Reply. *See* Paper 40 ("Pet. Reply"). Patent Owner filed a Sur-Reply. *See* Paper 32 ("PO Sur-Reply"). An oral hearing was held on August 12, 2021, and the hearing transcript is included in the record. *See* Paper 49 ("Tr.").

We have jurisdiction under 35 U.S.C. § 6(b). This is a Final Written Decision under 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons set forth below, we find Petitioner has failed to show by a preponderance of evidence that claims 1–16, 18, 23–38, and 40 of the '479 patent are unpatentable on the grounds raised in the Petition.

[1] Unless otherwise noted, we cite to the public versions of the papers in this proceeding. Earlier public versions of Patent Owner's Response (Paper 16) and Petitioner's Reply (Paper 23) were rejected for redacting more information than needed to protect Patent Owner's confidentiality interest. *See* Paper 30, 7–8; Paper 31, 3–4.

B. Real Parties-in-Interest

Petitioner and Patent Owner identify themselves, respectively, as the real parties-in-interest. Pet. 1; Paper 5, 1.

C. Related Matters

Petitioner and Patent Owner identify *Corephotonics Ltd. v. Apple Inc.*, 5:19-cv-04809 (N.D. Cal.), as a district court proceeding that can affect or be affected by this proceeding, and Petitioner also identifies IPR2020-00906 as an *inter partes review* that can affect or be affected by this proceeding. Pet. 1; Paper 5, 1. In addition, we note that the '479 patent is part of a family of patents and patent applications that include at least U.S. Patent Nos. 10,326,942; 10,015,408; 9,661,233; and 9,185,291. Ex. 1001, code (63). Many of these patents were or currently are involved in *inter partes* review proceedings that could affect or be affected by a decision in this proceeding.

D. Evidence Relied Upon[2]

Reference		Effective Date	Exhibit
Parulski	US 7,859,588 B2	Dec. 28, 2010	1005
Richard Szeliski, *Computer Vision Algorithms and Applications*, 468–503 (2011) ("Szeliski")		2011	1013
Konno[3]	JP 2013/106289 A	May 30, 2013	1015
Stein	US 8,908,041 B2	Feb. 7, 2013[4]	1023

[2] Petitioner also relies upon the Declarations of Fredo Durand, Ph.D. (Exs. 1003, 1038) and José Sasián, Ph.D. (Ex. 1021).

[3] Konno is a certified translation of a Japanese Patent Application originally published in Japanese. *See* Ex. 1015, 34–59.

[4] Petitioner identifies Stein as prior art under 35 U.S.C. § 102(a)(2) based on the February 7, 2013 filing date of a provisional application to which Stein claims priority. *See* Pet. 9. Patent Owner does not dispute this. *See* PO Resp. 1–47.

Reference		Effective Date	Exhibit
Segall	US 8,406,569 B2	Mar. 26, 2013	1024

E. Instituted Grounds of Unpatentability

We instituted review on the following grounds:

Ground	Claims	35 U.S.C. §	References
1	1, 10–14, 16, 18, 23, 32–36, 38, 40	103(a)	Parulski, Konno
2	2–4, 24–26	103(a)	Parulski, Konno, Szeliski
3	5–9, 27–31	103(a)	Parulski, Konno, Szeliski, Segall
4	15, 37	103(a)	Parulski, Konno, Stein

II. ANALYSIS

A. The ’479 Patent

The ’479 patent is directed to “a thin (e.g., fitting in a cell-phone) dual-aperture zoom digital camera with fixed focal length lenses” that is configured to use “partial or full fusion to provide a fused image in still mode.” Ex. 1001, 3:18–23. Figure 1A, reproduced below, illustrates a dual-aperture zoom digital camera 100.

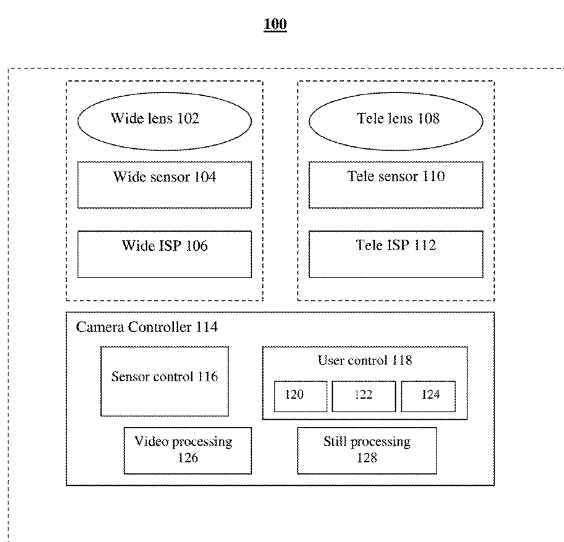

FIG. 1A

Figure 1A is a “block diagram illustrating a dual-aperture zoom” digital camera 100. *Id.* at 5:64–65. Camera 100 includes a wide imaging

subsystem consisting of wide lens 102, wide sensor 104, and wide image signal processor ("ISP") 106, and a tele imaging subsystem consisting of tele lens 108, tele sensor 110, and tele ISP 112. *Id.* at 6:24–29.

Camera 100 also includes controller 114, which includes sensor control 116, user control 118, video processing module 126 and still processing module 128. *Id.* at 6:33–37. User control 118 controls various camera functions, including, operational mode 120, region of interest ("ROI") 122, and zoom factor ("ZF") 124. *Id.* at 6:38–40. Zoom factor 124 allows a user "to choose a zoom factor." *Id.* at 6:50–51. Sensor control 116 chooses "which of the sensors is operational" based on the selected zoom factor. *Id.* at 6:41–45. ROI function 122 allows a user to "choose a region of interest," i.e., a sub-region "on which both sub-cameras are focused." *Id.* at 6:46–50.

The dual lenses allow camera 100 to take an image having a shallow depth-of-field ("DOF") "by taking advantage of the longer focal length of the Tele lens." *Id.* at 4:23–27. The image taken with the Tele lens can be enhanced "by fusing data from an image captured simultaneously with the Wide lens." *Id.* at 4:27–30. For example, the Tele lens can focus "on a subject of the photo" and the Wide lens can focus on "a closer distance than the subject so that objects behind the subject appear very blurry." *Id.* at 4:30–34. Then, a shallow depth-of-field image can be formed when "information from the out-of-focus blurred background in the Wide image is fused with the original Tele image background information, providing a blurrier background and even shallower DOF." *Id.* at 4:34–38.

The process for fusing images taken with the Wide and Tele lenses is shown in Figure 5 of the '479 patent, which is reproduced below.

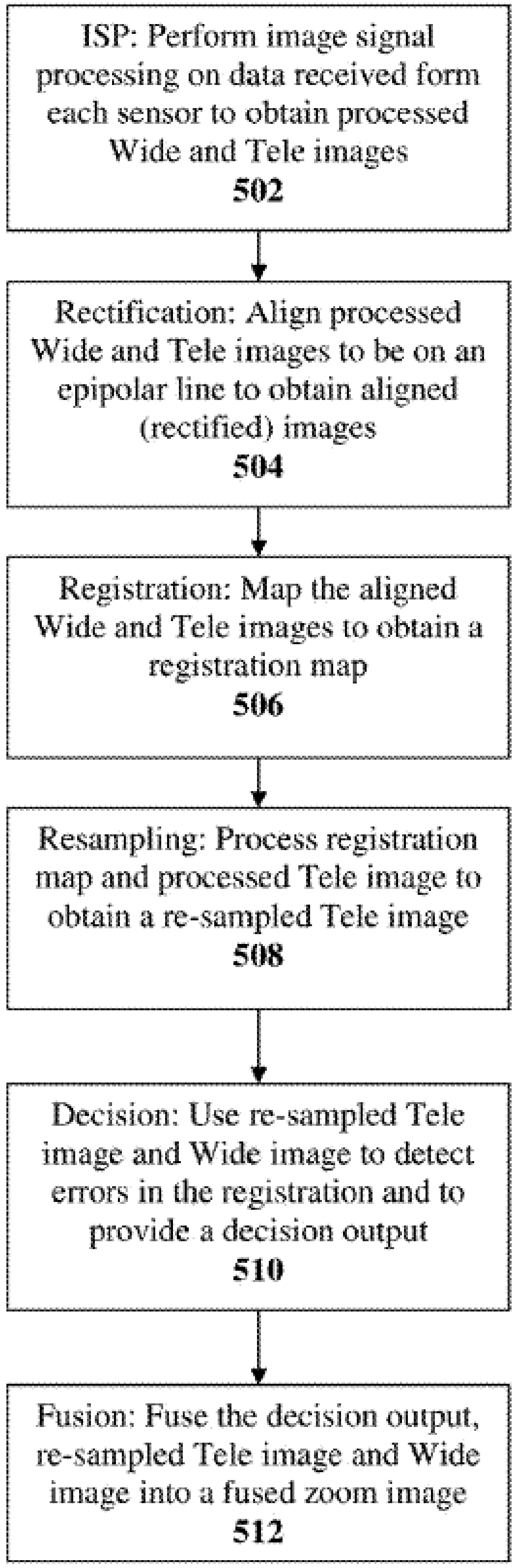
ISP: Perform image signal processing on data received form each sensor to obtain processed Wide and Tele images
502
Rectification: Align processed Wide and Tele images to be on an epipolar line to obtain aligned (rectified) images
504
Registration: Map the aligned Wide and Tele images to obtain a registration map
506
Resampling: Process registration map and processed Tele image to obtain a re-sampled Tele image
508
Decision: Use re-sampled Tele image and Wide image to detect errors in the registration and to provide a decision output
510
Fusion: Fuse the decision output, re-sampled Tele image and Wide image into a fused zoom image
512

Figure 5 is a flow chart depicting a method for acquiring a zoom image in a dual lens camera. *Id.* at 9:39–40. At step 502, separate images are captured by each of the Wide and Tele lenses. *Id.* at 9:40–44. At step 504, these images are aligned on an epipolar line. *Id.* at 9:46–47. At step 506, a registration map is generated. *Id.* at 9:47–49. At step 508, the registration map is used to resample the Tele image. *Id.* at 9:50–51. At step 510, Tele image pixel values are compared to Wide image pixel values, and if a significant difference is detected, the Wide image pixel values are chosen for the output image. *Id.* at 9:51–58. Finally, at step 512, a fused image is generated from the re-sampled Tele image and the Wide image. *Id.* at 9:58–60. The '906 patent discloses that by "register[ing] Tele image pixels to a matching pixel set within the Wide image pixels, . . . the output image will retain the Wide POV" or point-of-view. *Id.* at 5:23–26.

B. Illustrative Claims

Of the challenged claims, claims 1 and 23 are independent and substantially similar in scope. Claim 1 recites a dual-aperture digital camera configured to generate a fused image from images taken with wide angle and telephoto lenses, and claim 23 recites a method for generating such a fused image using a dual-aperture digital camera. *Compare* Ex. 1001, 13:22–50, *with id.* at 15:49–67. The remaining challenged claims depend directly or indirectly from claims 1 or 23. Claim 1 is illustrative of the challenged claims and is reproduced below.

> 1. A dual-aperture digital camera for imaging an object or scene, comprising:
>
> a) a Wide camera comprising a Wide lens and a Wide image sensor, the Wide camera having a respective field of view

FOV_W and being operative to provide a Wide image of the object or scene;

b) a Tele camera comprising a Tele lens and a Tele image sensor, the Tele camera having a respective field of view FOV_T narrower than FOV_W and being operative to provide a Tele image of the object or scene, wherein the Tele lens has a respective effective focal length EFL_T and total track length TTL_T fulfilling the condition $EFL_T / TTL_T > 1$;

c) a first autofocus (AF) mechanism coupled mechanically to, and used to perform an AF action on the Wide lens;

d) a second AF mechanism coupled mechanically to, and used to perform an AF action on the Tele lens; and

e) a camera controller operatively coupled to the first and second AF mechanisms and to the Wide and Tele image sensors and configured to control the AF mechanisms and to process the Wide and Tele images to create a fused image,

wherein areas in the Tele image that are not focused are not combined with the Wide image to create the fused image and

wherein the camera controller is further operative to output the fused image with a point of view (POV) of the Wide camera by mapping Tele image pixels to matching pixels within the Wide image.

Id. at 13:22–50.

C. Level of Ordinary Skill in the Art

Petitioner identifies a person of ordinary skill in the art ("POSITA") at the time of the invention as someone that would have had "a bachelor's or the equivalent degree in electrical and/or computer engineering or a related field and 2-3 years of experience in imaging systems including image processing and lens design." Pet. 6 (citing Ex. 1003 ¶ 13). In our Institution Decision, we adopted this description as our own. *See* Dec. Inst. 11–12.

Neither party disputes that preliminary finding, which we maintain for purposes of this decision. *See* PO Resp. 3–4; Pet. Reply 1–27.

D. Claim Construction

In *inter partes* reviews, we interpret a claim "using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. 282(b)." 37 C.F.R. § 42.100(b) (2019). Under this standard, a claim is construed "in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent." *Id.* Only claim terms which are in controversy need to be construed and only to the extent necessary to resolve the controversy. *See Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017).

In the Institution phase of this proceeding, Petitioner proposed a construction for a "fused image with a point of view (POV) of the Wide camera," which Patent Owner did not dispute. *See* Dec. Inst. 12. Therefore, we declined to expressly construe that or any other claim term. *Id.* In the current phase of this proceeding, Patent Owner disputes Petitioner's proposed construction for this term and argues Petitioner has failed to demonstrate how this limitation is met when it is properly construed. *See* PO Resp. 8–13, 29–31. Accordingly, we construe this term.

1. Fused Image with a Point of View (POV) of the Wide Camera

Petitioner contends this term means "a fused image that maintains the Wide camera's field of view or the Wide camera's position." Pet. 8 (emphasis omitted). Patent Owner contends it means a "fused image in which the positions and shapes of objects reflect the POV of the Wide camera." PO Resp. 13. Petitioner responds that Patent Owner's construction is unhelpful because it "fails to provide any meaning to the

construed term 'point of view (POV).'" Pet. Reply 1. Petitioner also provides an alternative construction that the term means a "fused image in which the positions or shapes of objects reflect those of the Wide camera." *Id.* at 6 (emphasis omitted). Patent Owner replies that this latter construction is new and improper and also incorrect because it "ignores that the [step of] registering pixels to matching pixels will necessarily address both position (shift) and perspective (shape)." PO Sur-Reply 2–3.

To resolve the parties' dispute, we turn to the Specification. *See Vitronics Corp. v. Conceptronic, Inc.*, 90 F.3d 1576, 1582 (Fed. Cir. 1996) ("[T]he specification is always highly relevant to the claim construction analysis. Usually, it is dispositive; it is the single best guide to the meaning of a disputed term."). In relevant part, the Specification discloses:

> In a dual-aperture camera image plane, as seen by each sub-camera (and respective image sensor), a given object will be shifted and have different perspective (shape). This is referred to as point-of-view (POV). The system output image can have the shape and position of either sub-camera image or the shape or position of a combination thereof. If the output image retains the Wide image shape then it has the Wide perspective POV. If it retains the Wide camera position then it has the Wide position POV. The same applies for Tele images position and perspective. As used in this description, the perspective POV may be of the Wide or Tele sub-cameras, while the position POV may shift continuously between the Wide and Tele sub-cameras. In fused images, it is possible to register Tele image pixels to a matching pixel set within the Wide image pixels, in which case the output image will retain the Wide POV ("Wide fusion").

Ex. 1001, 5:10–26.

Petitioner argues this disclosure supports its construction because it means "'*a point of view of the Wide camera'* . . . can mean one of two things—either 'Wide perspective POV' (i.e., wide camera FOV) or 'Wide

position POV' (i.e., wide camera position)." Pet. 7 (citing Ex. 1003 ¶ 31). Patent Owner argues this disclosure teaches a camera's point-of-view "depends on the position and orientation of the camera" and "using a camera with a different POV can both shift an object (change its position in the image) and change the perspective of an object (change[] its apparent shape in the image)." PO Resp. 12 (citing Ex. 2001 ¶ 43). Thus, when the '479 patent refers to "Wide POV" it "is referring to the complete Wide POV, both perspective and position." *Id.* at 13 (citing Ex. 2001 ¶ 45).

We agree with Patent Owner. Although it is not a model of clarity, the Specification equates a camera's POV with how an object will appear in that camera's image plane, e.g., in an image taken from that camera. For example, it discloses that "a given object will be shifted and have different perspective (shape). This is referred to as point-of-view (POV)." Ex. 1001, 5:10–12. Thus, the position *and* perspective (shape) of an object in an image depends on the POV of the camera that took the image.

The Specification further discloses that a fused image[5] that "retains the Wide image shape . . . has the Wide perspective POV" and a fused image that "retains the Wide camera position . . . has the Wide position POV." *Id.* at 5:15–18. Moreover, a fused image's "perspective POV may be of the Wide . . . sub-camera[], while the position POV may shift . . . between the Wide and Tele sub-cameras." *Id.* at 5:20–23. Thus, a fused image may have the Wide perspective POV and either (a) the Wide position POV, (b) the Tele position POV, or (c) an intermediate position POV. This suggests that a fused image has a Wide POV when it has both a Wide perspective POV

[5] A "fused" image is one that "combine[s] in still mode at least some of the Wide and Tele image data." Ex. 1001, 4:49–51.

and a Wide position POV. If the fused image did not have a Wide position POV it could only be described as having a Wide perspective POV, not a Wide POV.

Figure 5 of the ’479 patent, which is the only Figure that describes a method for generating a fused image, further suggests that a fused image has a Wide POV when it has both a Wide perspective POV and a Wide position POV. The method begins by aligning Wide and Tele images on an epipolar line and “mapping between the Wide and Tele aligned images . . . to produce a registration map.” *Id.* at 9:46–49. Next, after a re-sampling step, “the re-sampled Tele image and the Wide image are processed to detect errors in the registration.” *Id.* at 9:49–54. When an error is detected—i.e., when the “Tele image data is compared with the Wide image data and . . . the comparison detects significant dissimilarities”—the “Wide pixel values are chosen to be used in the output image.” *Id.* at 9:54–58. Thus, the fused image contains only information from (a) the Wide image and (b) the Tele image that matches information from the Wide image. The fused image contains no information from the Tele image that differs from information from the Wide image, e.g., information representing the different “shape” of an object when photographed from the POV of the Tele camera. As stated in the Specification, the process of “register[ing] Tele image pixels to a *matching pixel set* within the Wide image pixels . . . will retain the Wide POV.” *Id.* at 5:23–26 (emphasis added).

For the reasons discussed above, we agree with Patent Owner that a fused image having a Wide POV means a fused image in which the positions and shapes of objects reflect the POV of the Wide camera. Accordingly, we construe a fused image having a Wide POV to mean “a fused image having a Wide perspective POV and a Wide position POV.”

E. Ground 1

Petitioner argues claims 1, 10–14, 16, 18, 23, 32–36, 38, and 40 are unpatentable as obvious over Parulski and Konno. *See* Pet. 10–41. Patent Owner disputes this. *See* PO Resp. 26–31, 35–47. For the reasons discussed below, Petitioner has failed to establish by a preponderance of evidence that claims 1, 10–14, 16, 18, 23, 32–36, 38, and 40 are unpatentable as obvious over Parulski and Konno.

1. Parulski

Parulski discloses "a digital camera that uses multiple lenses and image sensors to provide an improved imaging capability." Ex. 1005, 1:8–10. A schematic illustration of Parulski's camera is shown in Figure 1, which is reproduced below.

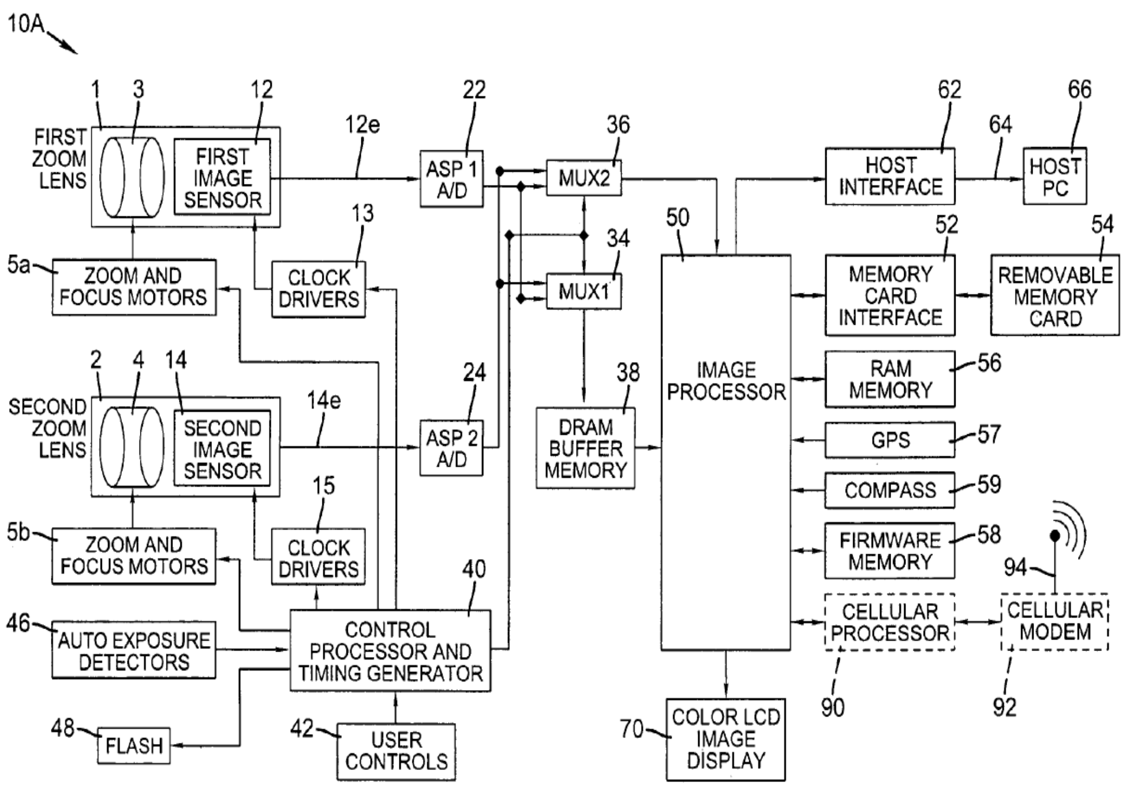

FIG. 1

with a first image sensor, and a second zoom lens with a second image sensor." *Id.* at 8:28–30.

The camera includes "two imaging stages 1 and 2, both with zoom lenses 3 and 4." *Id.* at 12:42–43. "[Z]oom lens 3 is controlled by a first lens focus adjuster, e.g., zoom and focus motors 5a, and provides an image to a first image sensor 12." *Id.* at 12:47–49. "[Z]oom lens 4 is controlled by a second lens focus adjuster, e.g., zoom and focus motors 5b, and provides an image to a second image sensor 14." *Id.* at 12:49–52. Each of zoom lenses 3 and 4 could be "replaced with a fixed focal length lens." *Id.* at 13:3–6. Image sensors 12 and 14 can "have a variety of aspect ratios" and "do not have to have the same specifications." *Id.* at 13:26–32. "[C]ontrol processor and timing generator 40 [CPT 40] controls the first image sensor 12 . . . the second image sensor 14" and "the zoom and focus motors 5a and 5b." *Id.* at 13:37–42. Analog data from image sensors 12 and 14 are digitized by analog signal processors 22 and 24, respectively, and the digitized data is supplied to each of multiplexers 34 and 36. *Id.* at 13:48–59. CPT 40 controls multiplexer 34 to select digitized data from either sensor 12 or 14 as an image signal and controls multiplexer 36 to select digitized data from the other of sensors 12 or 14 as an autofocus image signal. *Id.* at 14:1–5. Image processor 50 processes the digitized data from multiplexer 34 to produce a digital image and processes the digitized data from multiplexer 36 to calculate "focus detection signals that drive the first and second focus adjusters, that is, the zoom and focus motors 5a and 5b." *Id.* at 14:15–16.

Parulski's dual-lens camera can be used to generate a distance or range map as illustrated in Figure 11, which is reproduced below.

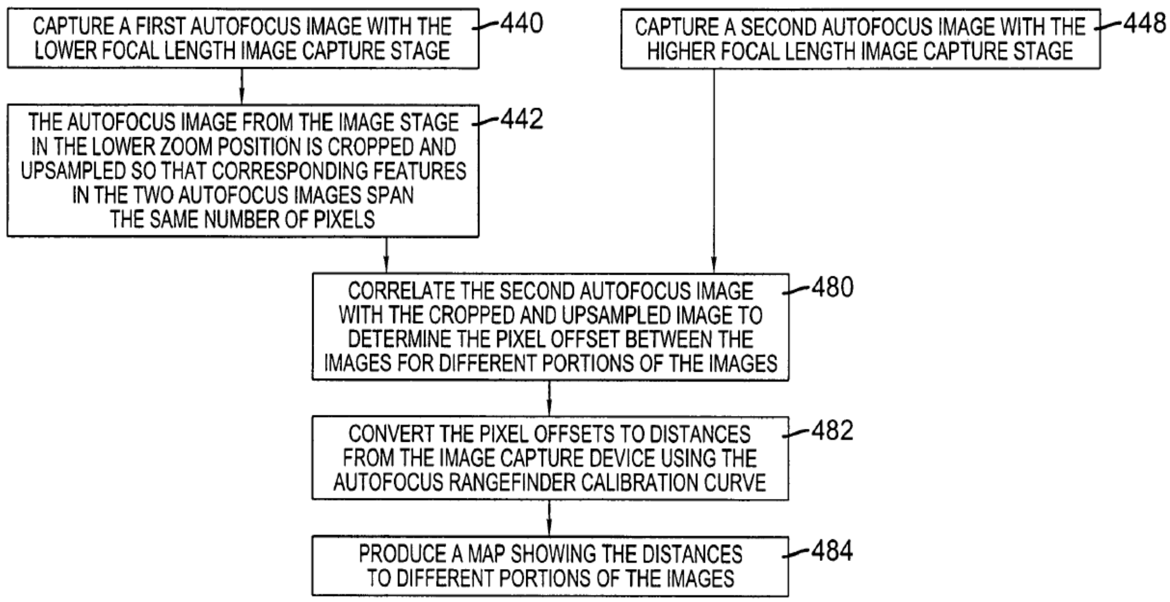

FIG. 11

Figure 11 is a flow chart showing a method for processing images captured with a two-lens camera to generate a distance or range map. *Id.* at 19:49–51. At step 440, "a first autofocus image is captured with the lower focal length image capture stage," e.g., lens 3 and image sensor 12. *Id.* at 20:1–3. At step 442, this image is "cropped and upsampled so that corresponding features in the two autofocus images span the same number of pixels." *Id.* at 20:3–6. At step 448, "a second autofocus image is captured with the higher focal length image capture stage," e.g., lens 4 and image sensor 14. *Id.* at 20:6–8. At step 480, "the second autofocus image is correlated with the cropped and upsampled image to determine the pixel offset between the images for different portions of the images." *Id.* at 20:8–11. At step 482, these pixel offsets are "converted . . . to distances from the image capture device using the autofocus rangefinder calibration curve." *Id.* at 20:11–14. Finally, at step 484, a distance or range map is produced "showing the distances to different portions of the images." *Id.* at 20:14–15.

Parulski's range map can be "used to modify the captured image signal or the output image for a variety of purposes," including "to enable dynamic depth of field images by blurring of portions of the image that correspond to areas of the scene that lie outside of the desired depth of field." *Id.* at 20:51–53, 20:63–65. For example, the range map can be used to modify a picture having a dog in the foreground, a field of flowers in the mid-ground, and a mountain range in the background. *Id.* at 21:7–17. "[I]f the user really wants to emphasize the dog more than the beautiful scenery, the range data can be used to isolate the mountains and the flowers, which can then be blurred." *Id.* at 21:27–30.

2. *Konno*

Konno discloses "an imaging apparatus . . . [that] includes single-focus first and second imaging optical systems that face the same direction." Ex. 1015 ¶ 7. Such a system is shown, for example, in Figure 21 of Konno, which is reproduced below.

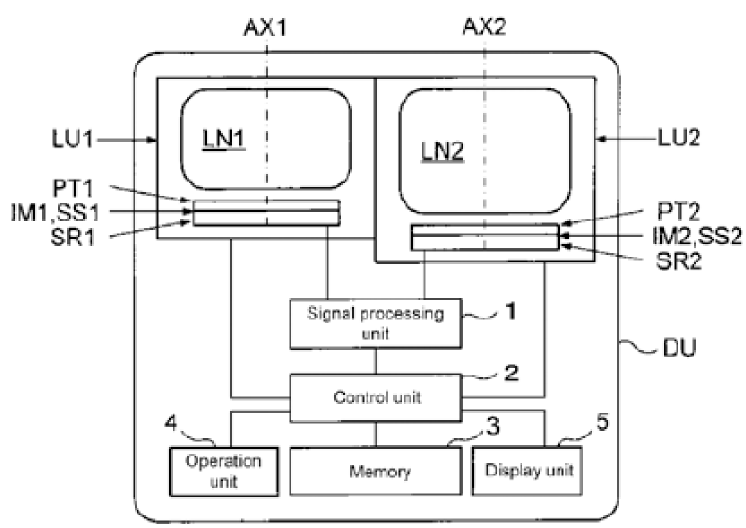

Figure 21 of Konna is "a schematic view . . . of digital equipment [e.g., a digital camera] including first and second imaging optical units." *Id.* ¶ 18. The digital camera includes optical units LU1 and LU2, which include

"single-focus first and second imaging optical systems [i.e., lenses] LN1 and LN2 . . . for forming optical images" and "first and second imaging devices [i.e., sensors] SR1 and SR2 for converting the optical images . . . into electrical signals." *Id.* ¶ 48. The camera also includes "a signal processing unit 1, a control unit 2, a memory 3, an operation unit 4, and a display unit 5." *Id.* ¶ 54. Control unit 2 "controls various functions including . . . a lens moving mechanism." *Id.* "[T]he first and second imaging optical systems [i.e., lenses] LN1 and LN2 have different focus movements in the case of whole feeding." *Id.* ¶ 50. Various characteristics of lenses LN1 and LN2 (e.g., focal length, lens length, field of view) are disclosed in Table 1 of Konno. *Id.* ¶ 76.

3. Reasons to Combine

Petitioner argues that it would have been obvious to combine the teachings of Parulski and Konno because "Parulski does not provide lens prescription data for either the first [wide] or second [tele] fixed-focus lenses in its cell phone" camera. Pet. 16. Thus, Petitioner argues, a skilled artisan "would have looked to Konno which provides a fixed-focal length, dual-lens system designed for digital equipment like cell phones." *Id.* at 16–17 (citing Ex. 1003 ¶ 57). Petitioner argues a person skilled in the art would have looked to Konno for lens prescription data because "Konno's system offers fixed-focal length wide and telephoto lenses in a thin format for incorporation in a mobile device," and "Parulski teaches the importance of keeping the 'z' dimension (i.e., thickness) of its cell phone embodiment small." *Id.* at 17; Ex. 1005, 24:20–27; Ex. 1015 ¶ 46. Patent Owner does not dispute these contentions. *See* PO Resp. 26–35.

We find Petitioner sets forth sufficient reasoning with rational underpinning to combine the teachings of Parulski and Konno. Parulski

teaches a cell phone having a dual-lens camera and the need to have thin lenses, but fails to give lens prescription data for the two camera lenses. Konno discloses lens prescription data for a dual-lens camera utilizing two thin lenses. The combination, therefore, is one of familiar elements according to known methods to obtain predictable results or a substitution of one element for another known in the field to obtain a predictable result. *See KSR Int'l Co. v. Teleflex, Inc.*, 550 U.S. 398, 416 (2007).

4. Claims 1 and 23

Claim 1 recites a dual-aperture digital camera having a Wide camera for providing a Wide image, a Tele camera for providing a Tele image, and a camera controller configured to process the Wide and Tele images to create a fused image. Ex. 1001, 13:22–34, 13:40–46. Claim 23 recites a method for acquiring a Wide image with a Wide sensor and a Tele image with a Tele sensor, and processing the Wide and Tele images to create a fused image. *Id.* at 15:49–64.

Figure 16A of Parulski discloses a dual-aperture camera having an assembly 610 that includes "a first fixed focal length lens 612 and a first image sensor 614, and a second fixed focal length lens 616 and a second image sensor 618," where "[t]he first lens 612 [is] preferably a fixed focal length wide angle lens . . . and the second lens 616 [is] preferably a fixed focal length telephoto lens." Ex. 1005, 23:28-40. Figure 14 of Parulski discloses "a method for enhancing the depth of field of an image by using images from both image capture stages," i.e., from the wide and tele lenses. *Id.* at 22:14–16. After capturing images from each of the wide and telephoto lenses, Parulski "*combine[s]* [them] into a modified image with a broadened depth of field." *Id.* at 28:45–53 (emphasis added).

Claim 1 further requires the camera controller to create and output the fused image with a point of view (POV) of the Wide camera by mapping Tele image pixels to matching pixels in the Wide image. Ex. 1001, 13:46–50. Claim 23 further requires the method of creating a fused image to include outputting the fused image with a point of view (POV) of the Wide camera by mapping Tele image pixels to matching pixels within the Wide image. *Id.* at 15:65–67.

To meet these limitations, Petitioner relies on several different disclosures in Parulski. *See* Pet. 26–30, 39, 40. For example, Parulski discloses modifying the depth of field of an image containing a dog in the foreground, a field of flowers in the mid-ground, and a snow-capped mountain in the background so that "the dog is in focus, the mountains are in focus and so are those great flowers." Ex. 1005, 21:9–13, 21:25–27. This is be done by combining information from two images, where one image "is captured . . . at one focus position [e.g., wide angle] and another image is captured . . . at another focus position [e.g., tele photo]." *Id.* at 28:45–53. The information to be combined can be obtained from the wide and tele images using a range map, which "improve[s] object identification within [an] image by identifying the continuous boundaries of the object so [its] shape . . . can be defined" and "enable[s] object extraction from an image by identifying the continuous boundaries of the object so it can be segmented within the image." *Id.* at 20:51–59. Petitioner argues that from these disclosures a person skilled in the art:

> would have understood that creating an enhanced image with both the mountains and the dog in focus would have meant that the pixel[s] corresponding to the dog from the telephoto image would have been identified by the range mapping process and then fused with the corresponding pixels in the wide image so

> that the dog would be sharpened in the wide image while maintaining the mountains in focus, thus broadening the wide image's depth of field.

Pet. 28 (citing Ex. 1003 ¶ 50).

Petitioner further argues Parulski's image fusing process maps Tele image pixels with matching pixels within the Wide image, as required by claims 1 and 23, because "Parulski's range map is generated by matching pixels from the telephoto image to matching pixels in the wide image." *Id.* at 30 (citing Ex. 1005, 20:1–15). Moreover, Petitioner argues, a person skilled in the art "would have understood that fusing portions of the telephoto image with the wide image . . . would have otherwise maintained the wide image, therefore outputting a fused image with the wide image's field of view." *Id.* at 29 (citing Ex. 1003 ¶¶ 50–51). That is, Petitioner argues that identifying and extracting pixels corresponding to the dog from the Tele image and fusing them with pixels corresponding to the dog from the Wide image would generate a fused image having the point of view (POV) of the Wide image because the resulting image would have the field of view (FOV) of the Wide image.

Patent Owner argues that Petitioner and Dr. Durand have failed to demonstrate that Parulski teaches "the 'fused image with a point of view (POV) of the Wide camera' limitation" because their "sole argument that Parulski meets this limitation is based on the output [image] having the 'wide image's field of view.'" PO Resp. 29 (citing Ex. 1003 ¶ 51). Patent Owner further argues that "[n]othing in Parulski suggests that whatever image data from the tele image that might be 'fused' into the output would be modified to have the shapes and positions from the wide image POV" and "nothing in Dr. Durand's declaration even attempts to establish [that] this

would be true." *Id.* at 30. Lastly, Patent Owner argues that Dr. Durand admitted during his deposition that he had not provided an opinion about whether Parulski generates a fused image having both a Wide perspective POV and a Wide position POV. *See* PO Sur-Reply 5 (citing Ex. 2041, 52:25–54:20).

We agree with Patent Owner. As we explain in § II.D.1, *supra,* claims 1 and 23 require generating a fused image having a Wide perspective POV and a Wide position POV. Petitioner's only argument for how the combination of Parulski and Konno teaches this limitation is Parulski's teaching of generating a fused image having a Wide position POV, i.e., having the field of view (FOV) of the Wide camera. *See* Pet. Reply 13 ("Parulski teaches . . . producing an output image that *maintains the Wide position POV or the field of view* of the Wide camera when the image was captured."). Petitioner fails to demonstrate how Parulski's image fusion method would also maintain the Wide perspective POV as required by independent claims 1 and 23.

Accordingly, for the reasons discussed above, Petitioner has failed to demonstrate by a preponderance of evidence that claims 1 and 23 are unpatentable as obvious over the combination of Parulski and Konno.

5. Claims 10–14, 16, 18, 32–36, 38, and 40

Claims 10–14, 16, and 18 depend, either directly or indirectly, from independent claim 1. *See* Ex. 1001, 14:29–44, 50–53, 61–65. Claims 32–36, 38, and 40 depend, either directly or indirectly, from independent claim 23. *Id.* at 16:41–54, 16:59–61, 17:1–4. Accordingly, for the reasons discussed in § II.E.4, *supra*, Petitioner has failed to demonstrate by a preponderance of evidence that claims 10–14, 16, 18, 32–36, 38, and 40 are unpatentable as obvious over the combination of Parulski and Konno.

F. Grounds 2–4

Petitioner argues claims 2–4 and 24–26 are unpatentable as obvious over Parulski, Konno, and Szeliski, claims 5–9 and 27–31 are unpatentable as obvious over Parulski, Konno, Szeliski, and Segall, and claims 15 and 37 are unpatentable as obvious over Parulski, Konno, and Stein. *See* Pet. 42–70. Patent Owner disputes this. *See* PO Resp. 31–47.

Claims 2–9 and 15 depend, either directly or indirectly, from independent claim 1. *See* Ex. 1001, 13:51–67, 14:1–28, 14:45–49. Claims 24–31 and 37 depend, either directly or indirectly, from independent claim 23. *Id.* at 16:1–40, 16:55–58. Accordingly, for the reasons discussed in § II.E.4, *supra,* Petitioner has failed to demonstrate by a preponderance of evidence that claims 2–9, 15, 24–31, and 37 are unpatentable as obvious over the combination of Parulski, Konno, and one or more of Szeliski, Segall, and Stein.

III. CONCLUSION

We have reviewed the Petition, Patent Owner Response, Petitioner Reply, and Patent Owner Sur-Reply. We have considered all of the evidence and arguments presented by Petitioner and Patent Owner, and have weighed and assessed the entirety of the evidence as a whole. We find, on this record, Petitioner has failed to demonstrate by a preponderance of evidence that claims 1–16, 18, 23–38, and 40 of the ’479 patent are unpatentable.

Claims	**35 U.S.C. §**	**Reference(s) /Basis**	**Claims Shown Unpatentable**	**Claims Not Shown Unpatentable**
1, 10–14, 16, 18, 23, 32–36, 38, 40	103(a)	Parulski, Konno		1, 10–14, 16, 18, 23, 32–36, 38, 40
2–4, 24–26	103(a)	Parulski, Konno,		2–4, 24–26

		Szeliski		
5–9, 27–31	103(a)	Parulski, Konno, Szeliski, Segall		5–9, 27–31
15, 37	103(a)	Parulski, Konno, Stein		15, 37
Overall Outcome				1–16, 18, 23–38, 40

IV. ORDER

In consideration of the foregoing, it is hereby:

ORDERED that Petitioner has failed to show on this record that claims 1, 10–14, 16, 18, 23, 32–36, 38, and 40 are unpatentable under 35 U.S.C. § 103(a) over Parulski and Konno; and

FURTHER ORDERED that Petitioner has failed to show on this record that claims 2–4 and 24–26 are unpatentable under 35 U.S.C. § 103(a) over Parulski, Konno, and Szeliski; and

FURTHER ORDERED that Petitioner has failed to show on this record that claims 5–9 and 27–31 are unpatentable under 35 U.S.C. § 103(a) over Parulski, Konno, Szeliski, and Segall; and

FURTHER ORDERED that Petitioner has failed to show on this record that claims 15 and 37 are unpatentable under 35 U.S.C. § 103(a) over Parulski, Konno, and Stein; and

FURTHER ORDERED that this Decision is final, and a party to this proceeding seeking judicial review of the Decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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Paper 54
Date: November 8, 2021

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

APPLE, INC.,
Petitioner,

v.

COREPHOTONICS LTD.,
Patent Owner.

IPR2020-00906
Patent 10,225,479 B2

Before BRYAN F. MOORE, JOHN F. HORVATH, and
MONICA S. ULLAGADDI, *Administrative Patent Judges.*

HORVATH, *Administrative Patent Judge*.

JUDGMENT
Determining No Challenged Claims Unpatentable
35 U.S.C. § 318(a)

I. INTRODUCTION

A. Background and Summary

Apple, Inc. ("Petitioner") filed a Petition requesting *inter partes* review of claims 19–22 ("the challenged claims") of U.S. Patent No. 10,225,479 B2 (Ex. 1001, "the '479 patent"). Paper 3 ("Pet."), 10. Corephotonics Ltd. ("Patent Owner") filed a Preliminary Response. Paper 8 ("Prelim. Resp."). Upon consideration of the Petition and Preliminary Response, we instituted *inter partes* review of all challenged claims on all grounds raised. Paper 10 ("Dec. Inst.").

Patent Owner filed confidential (Paper 15) and public (Paper 16) versions of a Response to the Petition. *See* Paper 16 ("PO Resp.").[1] Petitioner filed confidential (Paper 24) and public (Paper 23) versions of a Reply. *See* Paper 23 ("Pet. Reply"). Patent Owner filed a Sur-Reply. *See* Paper 33 ("PO Sur-Reply"). An oral hearing was held on August 12, 2021, and the hearing transcript is included in the record. *See* Paper 52 ("Tr.").

We have jurisdiction under 35 U.S.C. § 6(b). This is a Final Written Decision under 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons set forth below, we find Petitioner has failed to demonstrate by a preponderance of evidence that claims 19–22 of the '479 patent are unpatentable on the grounds raised in the Petition.

B. Real Parties-in-Interest

Petitioner and Patent Owner identify themselves, respectively, as the real parties-in-interest. Pet. 1; Paper 5, 1.

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[1] Throughout this Decision, unless noted otherwise, we cite to the public versions of the papers filed by the parties.

C. Related Matters

Petitioner and Patent Owner identify *Corephotonics Ltd. v. Apple Inc.*, 5:19-cv-04809 (N.D. Cal.), as a district court proceeding that can affect or be affected by this proceeding, and Petitioner also identifies IPR2020-00905 as an *inter partes review* that can affect or be affected by this proceeding. Pet. 1; Paper 5, 1. In addition, we note that the ’479 patent is part of a family of patents and patent applications that include at least U.S. Patent Nos. 10,326,942; 10,015,408; 9,661,233; and 9,185, 291. Ex. 1001, code (63). Many of these patents were or currently are involved in *inter partes* review proceedings that could affect or be affected by a decision in this proceeding.

D. Evidence Relied Upon[2]

Reference		Effective Date	Exhibit
Parulski	US 7,859,588 B2	Dec. 28, 2010	1005
Soga[3]	JP 2007/259108 A	Oct. 4, 2007	1006
Morgan-Mar	US 8,989,517 B2	Mar. 24, 2015	1009
Kawamura[4]	JP S5862609 A	Apr. 14, 1983	1012
Ogata	US 5,546,236	Aug. 13, 1996	1026

E. Instituted Grounds of Unpatentability

We instituted review on the following grounds:

Ground	Claims	35 U.S.C. §	References
1	19, 20	103(a)	Parulski, Ogata, Kawamura, Soga

[2] Petitioner also relies upon the Declarations of Fredo Durand, Ph.D. (Exs.1003, 1038) and José Sasián, Ph.D. (Exs. 1021, 1039).
[3] Soga is a *non-certified* translation of a Japanese Patent Application Publication originally published in Japanese. *See* Ex. 1006, 18–30.
[4] Kawamura is a certified translation of an Unexamined Japanese Patent Application Publication originally published in Japanese. *See* Ex. 1012, 10–16.

Ground	Claims	35 U.S.C. §	References
2	21, 22	103(a)	Parulski, Ogata, Kawamura, Soga, Morgan-Mar

II. ANALYSIS

A. The ’479 Patent

The ’479 patent is directed to “a thin (e.g., fitting in a cell-phone) dual-aperture zoom digital camera with fixed focal length lenses” that is configured to use “partial or full fusion to provide a fused image in still mode.” Ex. 1001, 3:18–23. Figure 1A, reproduced below, illustrates dual-aperture zoom digital camera 100.

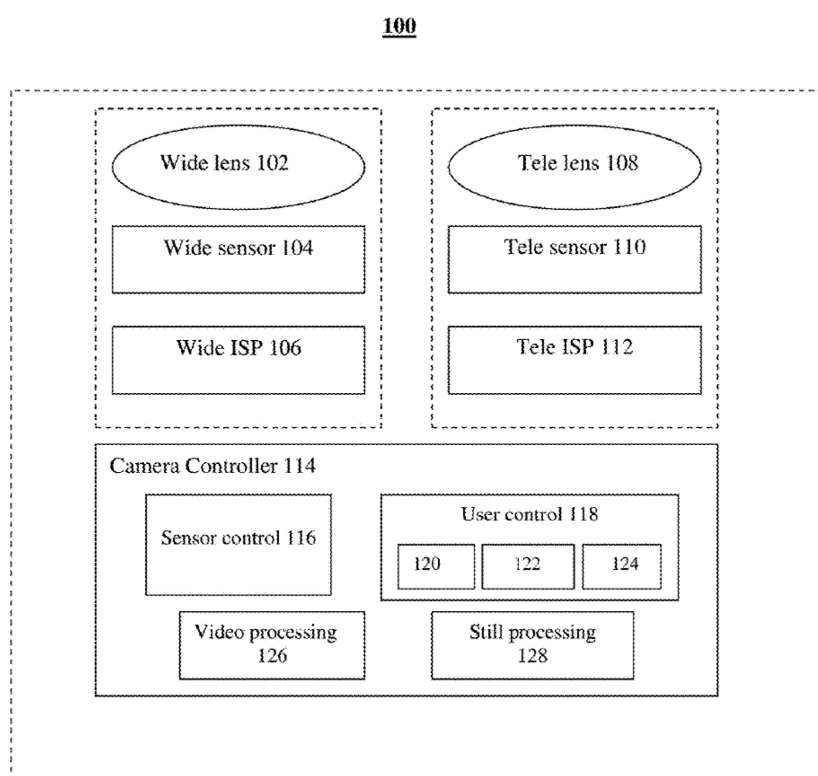

FIG. 1A

Figure 1A is a “block diagram illustrating a dual-aperture zoom” digital camera 100. *Id.* at 5:64–65. Camera 100 includes a wide imaging subsystem consisting of wide lens 102, wide sensor 104, and wide image

signal processor ("ISP") 106, and a tele imaging subsystem consisting of tele lens 108, tele sensor 110, and tele ISP 112. *Id.* at 6:24–29.

Camera 100 also includes controller 114, which includes sensor control 116, user control 118, video processing module 126 and still processing module 128. *Id.* at 6:33–37. User control 118 controls various camera functions, including, operational mode 120, region of interest ("ROI") 122, and zoom factor ("ZF") 124. *Id.* at 6:38–40. Zoom factor 124 allows a user "to choose a zoom factor." *Id.* at 6:50–51. Sensor control 116 chooses "which of the sensors is operational" based on the selected zoom factor. *Id.* at 6:41–45. ROI function 122 allows a user to "choose a region of interest," i.e., a sub-region "on which both sub-cameras are focused." *Id.* at 6:46–50.

The dual lenses allow camera 100 to take an image having a shallow depth-of-field ("DOF") "by taking advantage of the longer focal length of the Tele lens." *Id.* at 4:23–27. The image taken with the Tele lens can be enhanced "by fusing data from an image captured simultaneously with the Wide lens." *Id.* at 4:27–30. For example, the Tele lens can focus "on a subject of the photo" and the Wide lens can focus on "a closer distance than the subject so that objects behind the subject appear very blurry." *Id.* at 4:30–34. Then, a shallow depth-of-field image can be formed when "information from the out-of-focus blurred background in the Wide image is fused with the original Tele image background information, providing a blurrier background and even shallower DOF." *Id.* at 4:34–38.

The process for fusing images taken with the Wide and Tele lenses is shown in Figure 5 of the '479 patent, which is reproduced below.

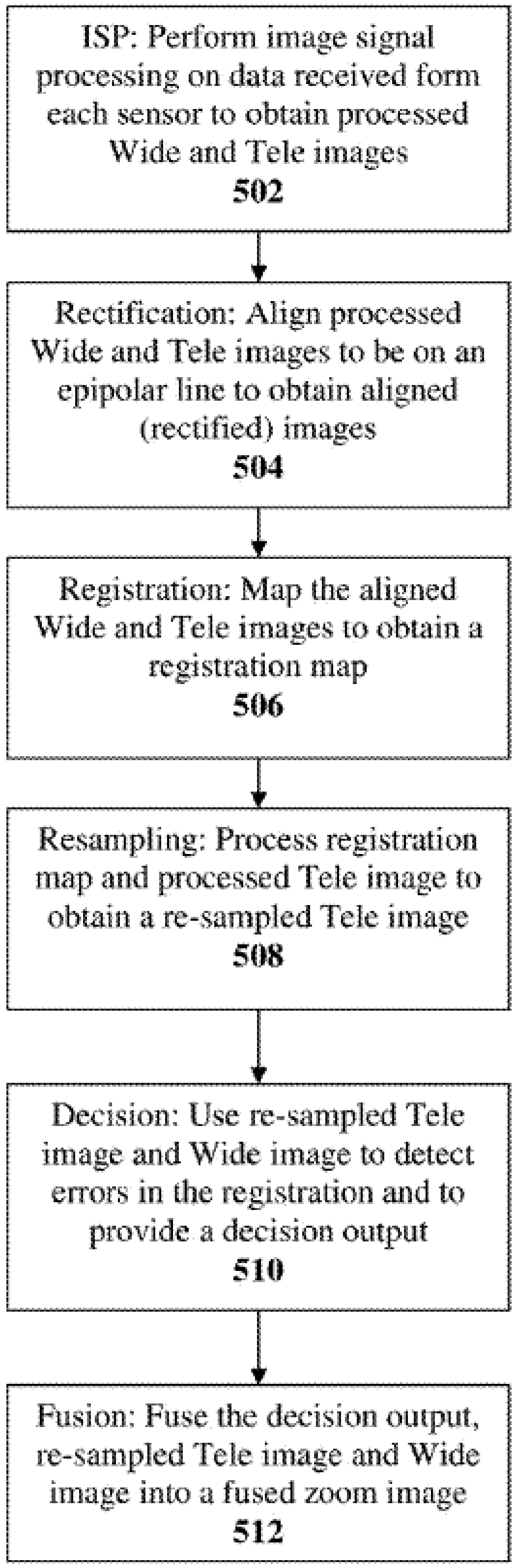
ISP: Perform image signal processing on data received form each sensor to obtain processed Wide and Tele images
502
Rectification: Align processed Wide and Tele images to be on an epipolar line to obtain aligned (rectified) images
504
Registration: Map the aligned Wide and Tele images to obtain a registration map
506
Resampling: Process registration map and processed Tele image to obtain a re-sampled Tele image
508
Decision: Use re-sampled Tele image and Wide image to detect errors in the registration and to provide a decision output
510
Fusion: Fuse the decision output, re-sampled Tele image and Wide image into a fused zoom image
512

Figure 5 is a flow chart depicting a method for acquiring a zoom image in a dual lens camera. *Id.* at 9:39–40. At step 502, separate images are captured by each of the Wide and Tele lenses. *Id.* at 9:40–44. At step 504, these images are aligned on an epipolar line. *Id.* at 9:46–47. At step 506, a registration map is generated. *Id.* at 9:47–49. At step 508, the registration map is used to resample the Tele image. *Id.* at 9:50–51. At step 510, Tele image pixel values are compared to Wide image pixel values, and if a significant difference is detected, the Wide image pixel values are chosen for the output image. *Id.* at 9:51–58. Finally, at step 512, a fused image is generated from the re-sampled Tele image and the Wide image. *Id.* at 9:58–60.

B. Illustrative Claim

Claims 19 is the only independent claim challenged. *See* Ex. 1001, 14:66–15:32. Claims 20–22 depend directly or indirectly from claim 19. *Id.* at 15:33–15:48. Claim 19 is illustrative of the challenged claims and is reproduced below.

> 19. A dual-aperture digital camera for imaging an object or scene, comprising:
>
> a) a Wide camera comprising a Wide lens and a Wide image sensor, the Wide camera having a respective field of view FOV_W and being operative to provide a Wide image of the object or scene;
>
> b) a Tele camera comprising a Tele lens and a Tele image sensor, the Tele camera having a respective field of view FOV_T narrower than FOV_W and being operative to provide a Tele image of the object or scene, wherein the Tele lens has a respective effective focal length EFL_T and total track length TTL_T fulfilling the condition $EFL_T/TTL_T > 1$;
>
> c) a first autofocus (AF) mechanism coupled mechanically to, and used to perform an AF action on the Wide lens;

> d) a second AF mechanism coupled mechanically to, and used to perform an AF action on the Tele lens, wherein the Wide and Tele lenses have different F numbers $F\#_{Wide}$ and $F\#_{Tele}$, wherein the Wide and Tele image sensors have pixels with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ wherein Pixel $size_{Wide}$ is not equal to Pixel $size_{Tele}$, and wherein the Tele camera has a Tele camera depth of field (DOF_T) shallower that a DOF of the Wide camera (DOF_W); and
>
> e) a camera controller operatively coupled to the first and second AF mechanisms and to the Wide and Tele image sensors and configured to control the AF mechanisms, to process the Wide and Tele images to find translations between matching points in the images to calculate depth information and to create a fused image suited for portrait photos, the fused image having a DOF shallower than DOF_T and having a blurred background.

Id. at 14:66–15:32.

C. Level of Ordinary Skill in the Art

Petitioner identifies a person of ordinary skill in the art ("POSITA") at the time of the invention as someone that would have had "a bachelor's or the equivalent degree in electrical and/or computer engineering or a related field and 2-3 years of experience in imaging systems including optics and image processing." Pet. 7 (citing Ex. 1003 ¶ 13). In our Institution Decision, we adopted this description as our own. *See* Dec. Inst. 9–10. Neither party disputes that preliminary finding, which we maintain for purposes of this decision. *See* PO Resp. 4–5; Pet. Reply 1–26.

D. Claim Construction

In *inter partes* reviews, we interpret a claim "using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. 282(b)." 37 C.F.R. § 42.100(b) (2019). Under this standard, a claim is construed "in accordance with the ordinary and

customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent." *Id.* Only claim terms which are in controversy need to be construed and only to the extent necessary to resolve the controversy. *See Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017).

The parties dispute the meaning of the camera controller limitation recited in claim 19. *See* Pet. 8–10; PO Resp. 9–11; Pet. Reply 1–4; PO Sur-Reply 2–3. We did not provide a preliminary construction for this term in our Institution Decision because Patent Owner initially did not dispute Petitioner's proposed construction or argue for an alternative construction. *See* Dec. Inst. 10–11. Although the parties currently dispute the meaning of this limitation, we need not construe it because our decision does not depend on its meaning. *See Nidec*, 868 F.3d at 1017.

E. Patentability of Claims 19–21

Petitioner argues claims 19 and 20 are unpatentable over Parulski, Ogata, Kawamura, and Soga, and claims 20 and 21 are unpatentable over Parulski, Ogata, Kawamura, Soga, and Morgan-Mar. Pet. 12–74. Patent Owner disagrees. PO Resp. 36–80.

For the reasons discussed below, we find Petitioner has failed to produce sufficient evidence to demonstrate that a person having ordinary skill in the art would have known that a scaled version of Ogata's lens could have been used in Parulski's camera with reasonable expectation of success. This failure is dispositive of all grounds in the Petition. Accordingly, we limit our analysis below to the evidence and argument presented regarding the teachings of Parulski, Ogata, and the reasons to combine these references.

1. Parulski

Parulski discloses "a digital camera that uses multiple lenses and image sensors to provide an improved imaging capability." Ex. 1005, 1:8–10. A schematic illustration of Parulski's camera is shown in Figure 1, which is reproduced below.

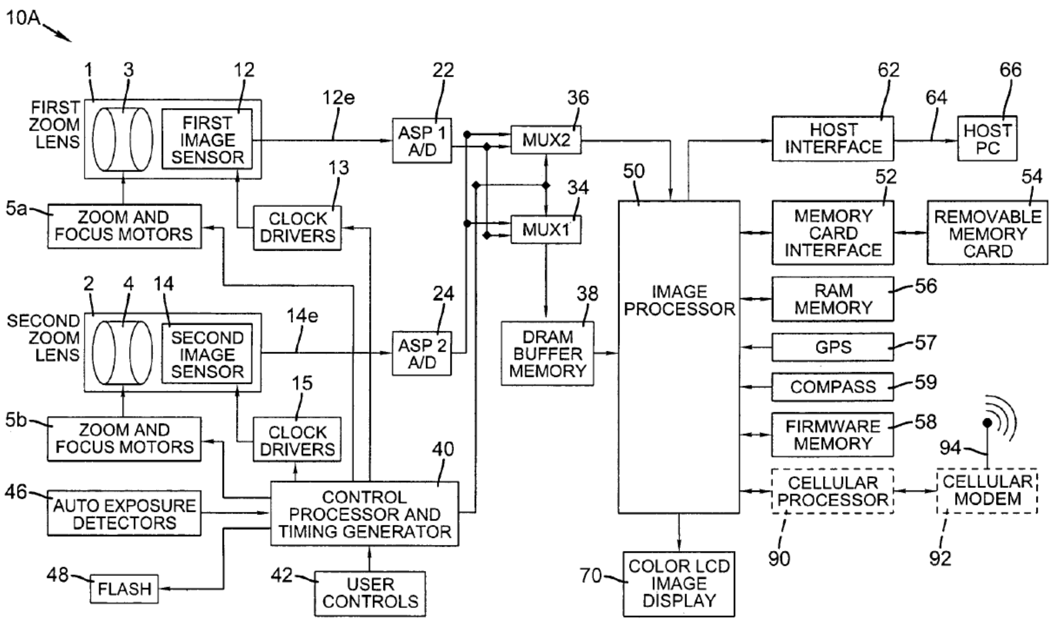

FIG. 1

Figure 1 is "a block diagram . . . of a digital camera using a first zoom lens [3] with a first image sensor [12], and a second zoom lens [4] with a second image sensor [14]." *Id.* at 8:28–30, Fig. 1. Each of zoom lenses 3 and 4 could be "replaced with a fixed focal length lens." *Id.* at 13:3–6. Image sensors 12 and 14 can "have a variety of aspect ratios" and "do not have to have the same specifications." *Id.* at 13:26–32. Parulski's digital camera could be, for example, the Kodak Easyshare V610 dual lens digital camera, which uses a 6MP (megapixel) 1/2.5" charge coupled device (CCD) as an image sensor. *Id.* at 5:21–35; *see also* Ex. 1033, 62 (showing the Easyshare V610 uses a 6 MP 1/2.5" CCD). Charge coupled devices of this type were rectangular with a 7.18 mm diagonal. *See* Ex. 1030, 1.

In Parulski's digital camera, analog data captured by image sensors 12 and 14 are digitized by analog signal processors 22 and 24, respectively, and sent to multiplexers 34 and 36. Ex. 1005, 13:48–59. Control processor 40 uses multiplexer 34 to select data from one of image sensors 12 or 14 as image data and uses multiplexer 36 to select data from the other of image sensors 12 or 14 as autofocus data. *Id.* at 14:1–5. Image processor 50 generates an image from the selected image data and autofocus signals for first and second zoom lenses 3 and 4 from the selected autofocus data. *Id.* at 14:5–16.

2. Ogata

Ogata discloses "[a] wide-angle photographic lens system which has a short total length . . . a high aperture ratio and excellent optical performance, and is suited for use with the collapsible mount type cameras." Ex. 1026, 3:2–5. Ogata's wide-angle lens system is shown in Figure 1, which is reproduced below.

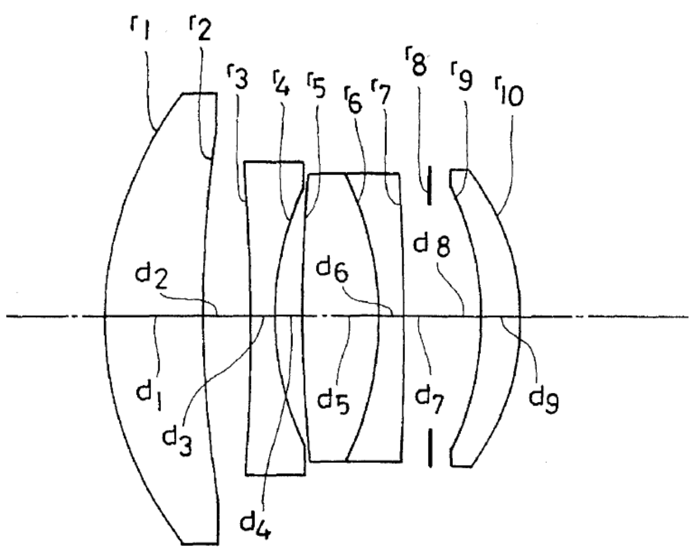

Figure 1 of Ogata is a schematic illustration of a first embodiment of Ogata's wide-angle lens system. *Id.* at 12:1–4.

Lens prescription data for the first embodiment of Ogata's lens is provided in tabular form in column 7. An annotated version of that table is reproduced below.

Embodiment I

$f = 35.0$, $f_B = 26.1$, F/2.9, $2\omega = 63.4°$

$r_1 = 14.1000$			
	$d_1 = 3.700$	$n_1 = 1.79952$	$\nu_1 = 42.24$
$r_2 = 47.5750$			
	$d_2 = 1.800$		
$r_3 = -81.2140$			
	$d_3 = 1.000$	$n_2 = 1.76182$	$\nu_2 = 26.52$
$r_4 = 12.0220$ (aspherical surface)			
	$d_4 = 1.000$		
$r_5 = 55.8920$			
	$d_5 = 3.000$	$n_3 = 1.83481$	$\nu_3 = 42.72$
$r_6 = -11.3420$			
	$d_6 = 1.000$	$n_4 = 1.53172$	$\nu_4 = 48.90$
$r_7 = -106.9860$			
	$d_7 = 1.000$		
$r_8 = \infty$ (stop)			
	$d_8 = 2.000$		
$r_9 = -10.4990$			
	$d_9 = 1.500$	$n_5 = 1.51633$	$\nu_5 = 64.15$
$r_{10} = -9.0360$ (aspherical surface)			

aspherical surface coefficients

(4th surface) $P = 1.0396$, $A_4 = 0.66373 \times 10^{-4}$
$A_6 = 0.13983 \times 10^{-5}$, $A_8 = -0.97157 \times 10^{-8}$
$A_{10} = 0.42114 \times 10^{-9}$

(10th surface) $P = 1.3037$, $A_4 = 0.44302 \times 10^{-4}$
$A_6 = -0.17498 \times 10^{-5}$, $A_8 = 0.10177 \times 10^{-6}$
$A_{10} = -0.17446 \times 10^{-8}$

$D_R/f = 0.043.$; $f_R/f = 2.660$, $(R_{2a} - r_{2b})/(r_{2a} + r_{2b}) = 1.347$,
$N_p = 1.717$, $r_{1a}/r_{2b} = 1.173$, $(r_{1b} - r_{2a})/r_{1b} + r_{2a}) = -3.829$,
$(r_{3a} - r_{3b})/(r_{3a} + r_{3b}) = -3.188$

Id. at 7:35–62. The Figure shows lens prescription data in tabular form for the first embodiment of Ogata's lens, annotated to highlight the index of refraction (n_3) and Abbe[5] number (υ_3) for the third lens element.

[5] An Abbe number is an approximate measure of how a material's index of refraction depends on the frequency of light passing through it. *See, e.g.*, Darryl Meister, Understanding Reference Wavelengths (April 12, 2010), available at http://www.opticampus.opti.vision/files/memo_on_reference_wavelengths.pdf (last visited October 18, 2021).

3. Reasons to Combine Parulski and Ogata

Petitioner argues that it would have been obvious to modify Parulski to include a scaled version of Ogata's wide-angle lens because "Parulski does not indicate lens prescription data for . . . [the] lens systems in its camera." Pet. 29. Thus, a skilled artisan would have looked to Ogata for "lens data that specifies the properties and configuration that teaches . . . how to construct a wide-angle lens unit." *Id.* (citing Ex. 1003 ¶ 63).

Petitioner argues that a skilled artisan would have known that the wide-angle lens described in Parulski ("40 mm equiv.") would have had a 56.8 degree FOV[6] and focused its image onto the 43.27 mm diameter image plane of a 35 mm camera. *Id.* at 29–30 (citing Ex. 1003 ¶ 68; Ex. 1005, 23:23–43; Ex. 1019, 107). Petitioner further argues that such an artisan would have also known that scaling Ogata's lens to instead focus its image onto the 7.12 mm diameter image plane of a 1/2.5" CCD would have resulted in a scaled lens having a similar 63.4 degree FOV and 2.9 F-number, but a 5.72 mm effective focal length (EFL) and a 6.89 mm total track length (TTL). *Id.* at 26–28 (citing Ex. 1005, 5:21–35; 1020, 57; Ex. 1021 ¶¶ 37–39; Ex. 1022, 254–255; Ex. 1026, 7:35–61, Fig. 1; Ex. 1029; Ex. 1030; Ex. 1033, 62).

Petitioner supports its argument with the testimonial evidence of Dr. Sasián. *See* Pet. 26–27 (citing Ex. 1021 ¶ 38). According to Dr. Sasián, a person skilled in the art could have used Zemax lens design software to scale Ogata's lens. Ex. 1021 ¶ 39 (citing Ex. 1021, App'x, Figs. 3A–3C). The appendix to Dr. Sasián's declaration includes a heading "C" entitled "Fig. 3 - Ogata scaled to fill a 1/2.5" image sensor using Zemax (v.02/14/2011)."

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[6] Corresponding to a 28.40 degree HFOV or half field-of-view.

Id. at 34.[7] The appendix also includes a heading "C.3" entitled "Figure 3C – Prescription Data," followed by a "Lens Data Editor" spreadsheet, an annotated version of which is reproduced below.[8]

3. *Fig. 3C – Prescription Data*

Lens Data Editor

Edit Solves View Help

Surf:Type		Comment	Radius	Thickness		Glass		Semi-Diameter		Conic	Par
OBJ	Standard		Infinity	Infinity				Infinity		0.000000000	
1*	Standard		2.306209846	0.605175633		1.80,42.2		1.308487856	U	0.000000000	
2*	Standard		7.781413719	0.294409768				1.144926874	U	0.000000000	
3*	Standard		-13.2834416	0.163560982		1.76,26.5		0.940475647	U	0.000000000	
4*	Even Asph..		1.966330126	0.163560982				0.830000000	U	0.039600000	
5*	Standard		9.141750406	0.490682946		1.83,26.5		0.900000000	U	0.000000000	
6*	Standard		-1.85510866	0.163560982		1.53,48.9		0.900000000	U	0.000000000	
7*	Standard		-17.4987352	0.163560982				0.858695155	U	0.000000000	
STO	Standard		Infinity	0.327121964				0.778746435		0.000000000	
9	Standard		-1.71722675	0.245341473		1.52,64.2		0.852109096		0.000000000	
10	Even Asph..		-1.47793703	4.274573517	M			0.936989741		0.303700000	
IMA	Standard		Infinity	-				3.569545975		0.000000000	

(unused)	2nd Order Term	4th Order Term	6th Order Term	8th Order Term	10th Order Term
	0.000000000	0.015168838	0.011945431	-3.103E-003	5.0270E-003
	0.000000000	0.010124748	-0.01494823	0.032498387	-0.02082469

The Figure is an annotated version of "Fig. 3C – Prescription Data" showing lens prescription data entered into a "Lens Data Editor" spreadsheet and

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[7] When citing to the appendix, we cite to the declaration page numbers.
[8] In Zemax, a "Lens Data Editor is the primary spreadsheet where the majority of the lens data will be entered." Ex. 1022, 789.

annotated to highlight the index of refraction (1.83) and Abbe number (26.5) of the third lens element in the "Glass" column.

A few inconsistencies between the lens prescription data for Ogata's first embodiment lens and the data entered into the "Lens Editor Data" spreadsheet are noticeable. First, the Abbe number for the third lens element is 42.72 in Ogata's first embodiment lens and 26.5 (i.e., 38% smaller) in the "Lens Data Editor" spreadsheet. *Compare* Ex. 1026, 7:46, *with* Ex. 1021, 36. Second, the data for the fourth and tenth aspherical surfaces are noticeably different. For example, the fourth order term (A_4) for the fourth aspherical surface is 0.66 x 10^{-4} in Ogata's first embodiment lens and 151.69 x 10^{-4} (i.e., 0.015) in the "Lens Data Editor" spreadsheet. *Compare* Ex. 1026, 7:55, *with* Ex. 1021, 36. Neither Petitioner nor Dr. Sasián explain these discrepancies.

Patent Owner identifies the Abbe number discrepancy for the third lens element between Ogata's first embodiment lens and the "Lens Data Editor" spreadsheet. *See* PO Resp. 31. Patent Owner argues that, due to this discrepancy, "Dr. Sasián's field curvature, distortion and OPD [optical path difference] fan plots on page 35 of his declaration do not accurately reflect the performance of a scaled version of Ogata's Embodiment 1 lens." *Id.* (citing Ex. 2015 ¶ 62). Moreover, Dr. Moore opines that "[a] significant change in the index of refraction or the Abbe number can change a highly performing lens design into an unacceptable design." Ex. 2015 ¶ 88.

Petitioner was provided an opportunity to try to explain or correct this Abbe number discrepancy in its Reply, but did not attempt to do so. *See* Pet. Reply, 1–26. Instead, Petitioner argued that "Petitioner and Dr. Sasián have provided detailed lens design software analysis, which confirms the viability of . . . Ogata's lens designs in Parulski and reinforces the Petition's

motivation to use the same." *Id.* at 15 (citing Pet. 21–24, 28–30; Ex. 1021 ¶¶ 35–45, App'x; Ex. 1039 ¶ 22, App'x).[9] But Dr. Sasián's lens design analysis appears to be based on the erroneous data discussed above, calling into question Petitioner's contention that a person skilled in the art would have known that Ogata's lens could be scaled to work in Parulski's camera with a reasonable expectation of success. Indeed, Petitioner criticized Patent Owner for offering opinions that were *not* based on lens design software analysis because a person skilled in the art "would have performed lens design software analysis and formed its opinion based on the lens design software." *Id.*

In an *inter partes* review, Petitioner is "master of its complaint." *SAS Institute, Inc. v. Iancu*, 138 S.Ct. 1348, 1355 (2018). Thus, the Petition is "the centerpiece of the proceeding both before and after institution." *Id.* at 1358. Moreover, Petitioner "has the burden from the onset to show with particularity why the patent it challenges is unpatentable." *Harmonic Inc. v. Avid Tech., Inc.*, 815 F.3d 1356, 1363 (Fed. Cir. 2016). Petitioner's contention that a person skilled in the art would have found it obvious that Ogata's lens could have been scaled to work in Parulski's camera with a reasonable expectation of success is entirely based on Dr. Sasián's opinion, which is based on Dr. Sasián's Zemax lens design software analysis. *See* Pet. 24–30; *see also* Ex. 1021 ¶¶ 35–39, App'x, 34–36. But, as noted above, the lens prescription data used for that analysis appears to differ from the

[9] Petitioner cites paragraphs 50–55 and 61–65 of Dr. Sasián's declaration, which has 46 enumerated paragraphs. *See* Ex. 1021, 27. Dr. Sasián analyzes scaling Ogata's lens in paragraphs 35–39 of his declaration and scaling Kawamura's lens in paragraphs 40–45. We make that correction here.

lens prescription data for Ogata's first embodiment lens.[10] *Compare* Ex. 1026, 7:46, *with* Ex. 1021, 36. We accept as true Petitioner's contention that a person skilled in the art "would have performed lens design software analysis and formed [an] opinion based on the lens design software." Pet. Reply 15 (citing Ex. 1039 ¶ 22). A logical consequence of that contention is that the opinion of a person skilled in the art will be only as reliable as the lens design software analysis that person performed, which will be only as reliable as the data used to perform that analysis.

Moreover, as also discussed above, Patent Owner pointed out this Abbe number discrepancy in its Patent Owner Response. *See* PO Resp. 31. This put Petitioner on notice of the discrepancy and shifted the burden of production to Petitioner to either correct its analysis or explain why the Abbe number discrepancy did not affect the analysis. *See Dynamic Drinkware, LLC v. National Graphics, Inc.*, 800 F.3d 1375, 1378 (Fed. Cir. 2015) (explaining the shifting burden of production in an *inter partes* review may require "producing additional evidence and presenting persuasive argument based on new evidence or evidence already of record") (internal citations omitted). Petitioner neither corrected its reason to combine analysis nor explained why it would not be affected by the apparent Abbe number discrepancy. *See* Pet. Reply 1–26.

Finally, in response to Patent Owner's argument that a person skilled in the art "would not have used the Ogata lens design scaled down," but would have instead constructed a miniature camera lens using "a fully

[10] We note, as well, that the lens prescription data for example 1 of Kawamura's lens appears to differ from the lens prescription data Dr. Sasián used to perform the Zemax analysis for scaling Kawamura's lens. *Compare* Ex. 1012, 3, *with* Ex. 1021, 37, 39.

aspheric design with plastic elements" having an aperture stop near the front of the lens (PO Resp. 58–59), Petitioner argues that a person of ordinary skill in the art "could have used lens design software to modify and adjust an older lens design into a miniaturized version" because the "modifications or adjustments [needed] were within the skill" level of a person of ordinary skill in the art (Pet. Reply 15–16 (citing Ex. 1039 ¶¶ 24–31)).[11] Patent Owner argues that "Dr. Sasián's new Zemax analyses should be disregarded as an untimely obviousness theory presented in reply" because "[t]he Zemax analyses in Dr. Sasián's original declaration simply took the lens prescriptions in the Kawamura and Ogata patents and confirmed that Zemax would scale them." PO Sur-Reply 13–14.

We agree with Patent Owner. The Petition contends that a person of ordinary skill in the art would have known that Ogata's lens (using glass lens elements) could have been *scaled* to focus an image onto a 1/2.5" image sensor for use in Parulski's camera. *See* Pet. 24–30; Ex. 1021, 36. Petitioner's reply evidence and argument is not introduced to support that contention but a different contention—that a person of ordinary skill in the art would have known that Ogata's lens could have been *redesigned* using aspheric plastic lens elements to focus an image onto a 1/3" image sensor. *See* n.11, *supra*. This is a new contention that does not support Petitioner's

[11] We note that Dr. Sasián's analysis discloses how Kawamura's lens can be modified by replacing the spherical glass lens elements with aspherical plastic lens elements, moving the aperture stop to the first lens element, changing the F number to 2.8, and reducing the effective focal length to focus an image onto a 1/3" image sensor rather than a 1/2.5" image sensor. *See* Ex. 1039 ¶¶ 25–30; App'x, 17–18. Dr. Sasián also opines that although this analysis illustrates how Kawamura's lens could have been modified, a person skilled in the art "would have recognized that Ogata could have been similarly adjusted to yield a miniaturized form-factor." *Id.* ¶ 25.

original contention that Ogata's lens could simply be scaled. Therefore, because it is a new and untimely contention, we do not consider it further. *See* Consolidated Trial Practice Guide (Nov. 2019)[12] ("Petitioner may not submit new evidence or argument in reply that it could have presented earlier, e.g., to make out a prima facie case of unpatentability."); *see also Ariosa Diagnostics v. Verinata Heath, Inc.*, 805 F.3d 1359, 1368 (Fed. Cir. 2015) ("The Board must make judgments about . . . when a Reply contention crosses the line from the responsive to the new."); *Intelligent Bio-Sys., Inc. v. Illumina Cambridge Ltd.*, 821 F.3d at 1359, 1369–70 (Fed. Cir. 2016) (affirming the Board's rejection of a reply argument presenting an "entirely new rationale to explain why one of skill in the art would have been motivated to combine" prior art references); *Henny Penny Corp. v. Frymaster LLC*, 938 F.3d 1324, 1330–31 (Fed. Cir. 2019) (affirming the Board's rejection of a reply argument presenting an "entirely new rationale" for why a claim would have been obvious).

For the reasons discussed above, we find Petitioner has failed to muster sufficient evidence to demonstrate by a preponderance of evidence that a person or ordinary skill in the art at the time of the invention would have known that Ogata's lens could have been scaled to work in Parulski's camera with a reasonable expectation of success. Accordingly, we find Petitioner has failed to demonstrate that claims 19 and 20 are unpatentable over Parulski, Ogata, Kawamura, and Soga or that claims 20 and 21 are unpatentable over Parulski, Ogata, Kawamura, Soga, and Morgan-Mar.

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[12] Available at https://www.uspto.gov/TrialPracticeGuideConsolidated

III. CONCLUSION

We have reviewed the Petition, Patent Owner Response, Petitioner Reply, and Patent Owner Sur-Reply. We find, on this record, Petitioner has failed to demonstrate by a preponderance of evidence that claims 19–22 of the ’479 patent are unpatentable.

Claims	**35 U.S.C. §**	**Reference(s) /Basis**	**Claims Shown Unpatentable**	**Claims Not Shown Unpatentable**
19, 20	103(a)	Parulski, Ogata, Kawamura, Soga		19, 20
21, 22	103(a)	Parulski, Ogata, Kawamura, Soga, Morgan-Mar		21, 22
Overall Outcome				19–22

IV. ORDER

In consideration of the foregoing, it is hereby:

ORDERED that Petitioner has failed to show by a preponderance of evidence that claims 19 and 20 are unpatentable under 35 U.S.C. § 103(a) over Parulski, Ogata, Kawamura, and Soga; and

FURTHER ORDERED that Petitioner has failed to show by a preponderance of evidence that claims 21 and 22 are unpatentable under 35 U.S.C. § 103(a) over Parulski, Ogata, Kawamura, Soga, and Morgan-Mar; and

FURTHER ORDERED that this Decision is final, and a party to this proceeding seeking judicial review of the Decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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US010225479B2

(12) **United States Patent**
Shabtay et al.

(10) **Patent No.: US 10,225,479 B2**
(45) **Date of Patent: Mar. 5, 2019**

(54) **DUAL APERTURE ZOOM DIGITAL CAMERA**

(71) Applicant: **Corephotonics Ltd.**, Tel Aviv (IL)

(72) Inventors: **Gal Shabtay**, Tel Aviv (IL); **Ephraim Goldenberg**, Ashdod (IL); **Oded Gigushinski**, Herzlia (IL); **Noy Cohen**, Tel Aviv (IL)

(73) Assignee: **Corephotonics Ltd.**, Tel Aviv (IL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/048,242**

(22) Filed: **Jul. 28, 2018**

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(Continued)

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(Continued)

(52) **U.S. Cl.**
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(Continued)

(58) **Field of Classification Search**
CPC G02B 13/0015; G02B 27/0075
See application file for complete search history.

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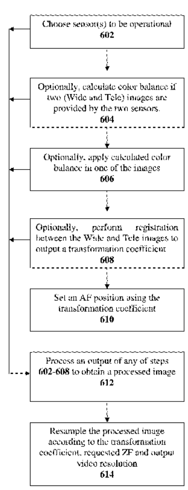
(57) **ABSTRACT**

A dual-aperture zoom digital camera operable in both still and video modes. The camera includes Wide and Tele imaging sections with respective lens/sensor combinations and image signal processors and a camera controller operatively coupled to the Wide and Tele imaging sections. The Wide and Tele imaging sections provide respective image data. The controller is configured to combine in still mode at least some of the Wide and Tele image data to provide a fused output image from a particular point of view, and to provide without fusion continuous zoom video mode output images, each output image having a given output resolution, wherein the video mode output images are provided with a smooth transition when switching between a lower zoom factor (ZF) value and a higher ZF value or vice versa, and wherein at the lower ZF the output resolution is determined by the Wide sensor while at the higher ZF value the output resolution is determined by the Tele sensor.

40 Claims, 8 Drawing Sheets



Related U.S. Application Data

No. 15/424,853, filed on Feb. 5, 2017, now Pat. No. 10,015,408, which is a continuation of application No. 14/880,251, filed on Oct. 11, 2015, now Pat. No. 9,661,233, which is a continuation of application No. 14/365,711, filed as application No. PCT/IB2014/062180 on Jun. 12, 2014, now Pat. No. 9,185,291.

(60) Provisional application No. 61/834,486, filed on Jun. 13, 2013.

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G02B 27/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 27/0075*** (2013.01); ***H04N 5/225*** (2013.01); ***H04N 5/2258*** (2013.01); ***H04N 5/2259*** (2013.01); ***H04N 5/23212*** (2013.01); ***H04N 5/23232*** (2013.01); ***H04N 5/23245*** (2013.01)

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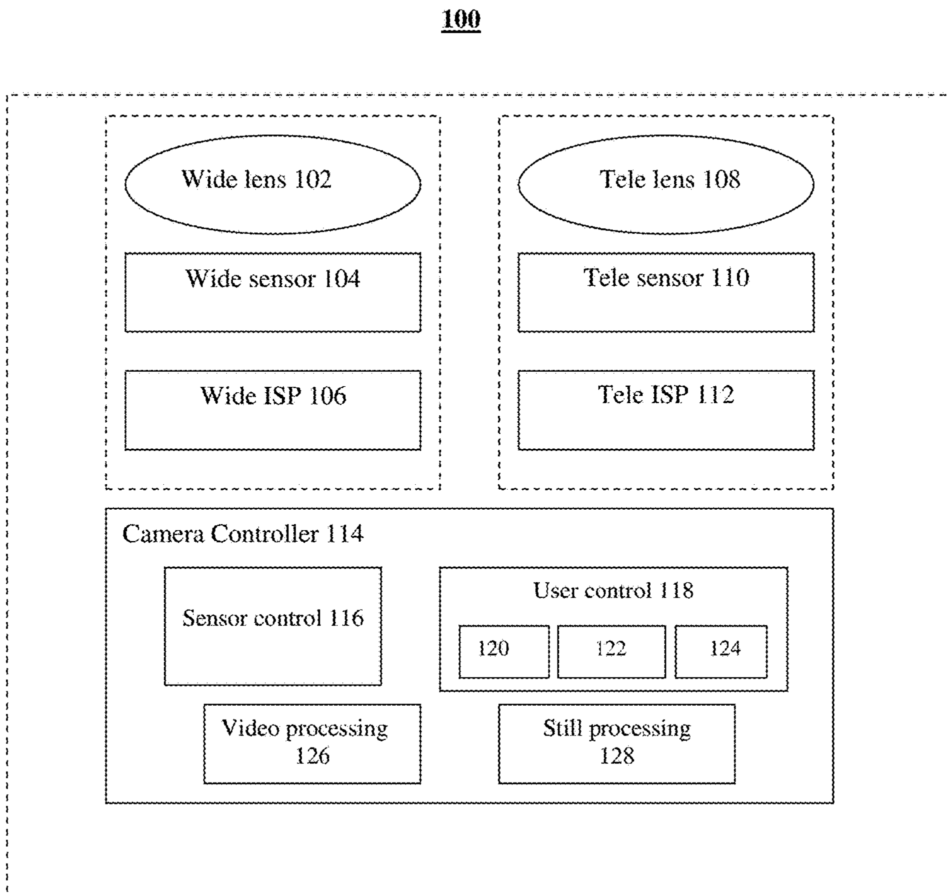

100
Wide lens 102
Tele lens 108
Wide sensor 104
Tele sensor 110
Wide ISP 106
Tele ISP 112
Camera Controller 114
Sensor control 116
User control 118
120
122
124
Video processing 126
Still processing 128

FIG. 1A

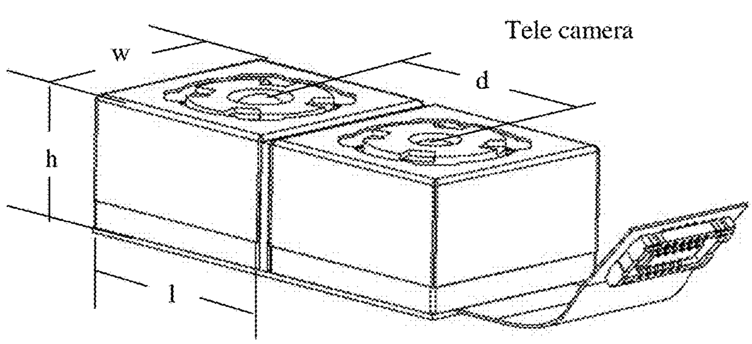

Tele camera
w
d
h
l

FIG. 1B

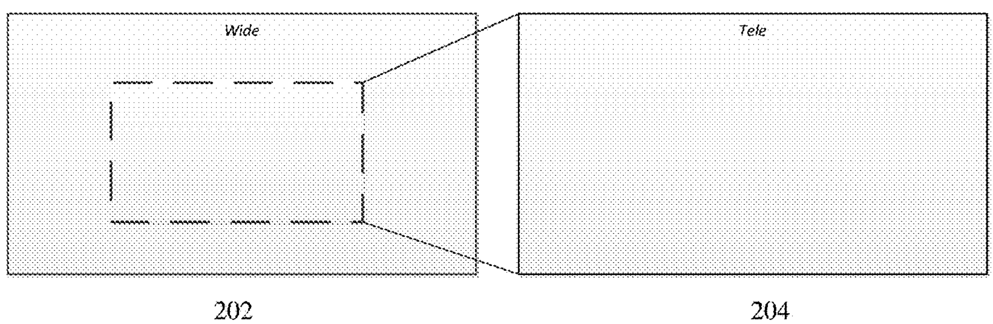
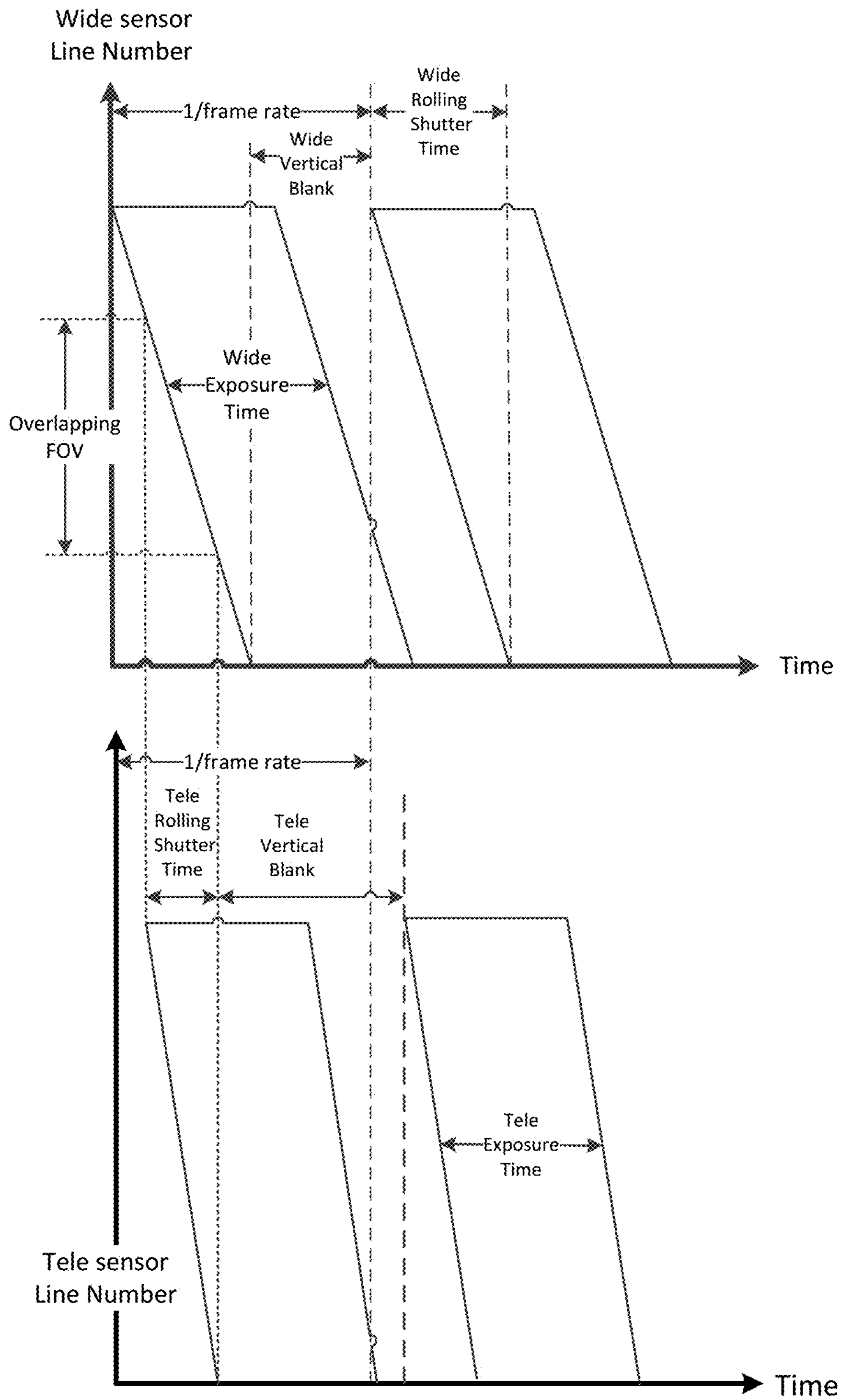


FIG. 2



Wide sensor Line Number
1/frame rate
Wide Rolling Shutter Time
Wide Vertical Blank
Wide Exposure Time
Overlapping FOV
Time
1/frame rate
Tele Rolling Shutter Time
Tele Vertical Blank
Tele Exposure Time
Tele sensor Line Number
Time

FIG. 3

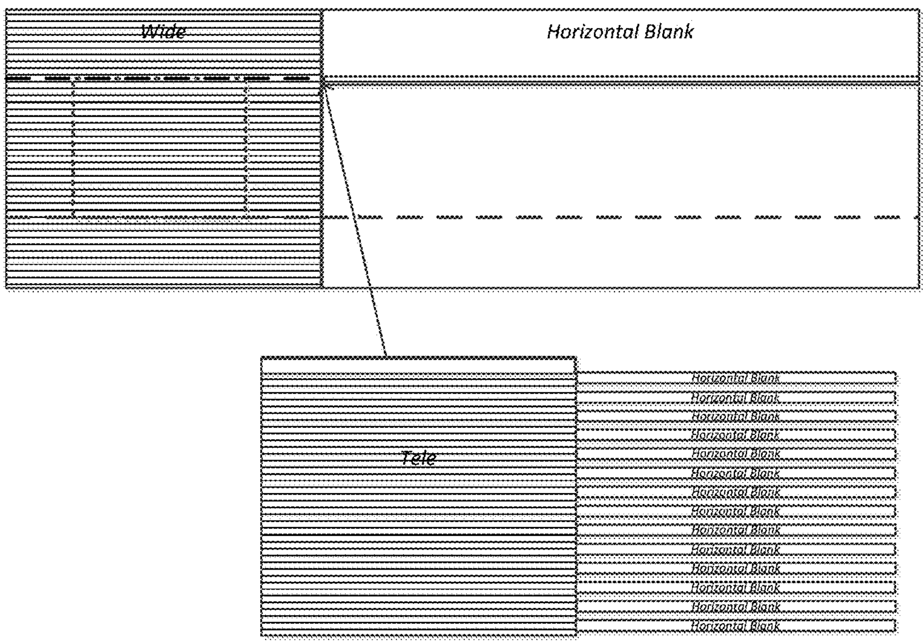

Wide
Horizontal Blank
Tele
Horizontal Blank
Horizontal Blank
Horizontal Blank
Horizontal Blank
Horizontal Blank
Horizontal Blank
Horizontal Blank
Horizontal Blank
Horizontal Blank
Horizontal Blank
Horizontal Blank
Horizontal Blank
Horizontal Blank
Horizontal Blank

FIG. 4

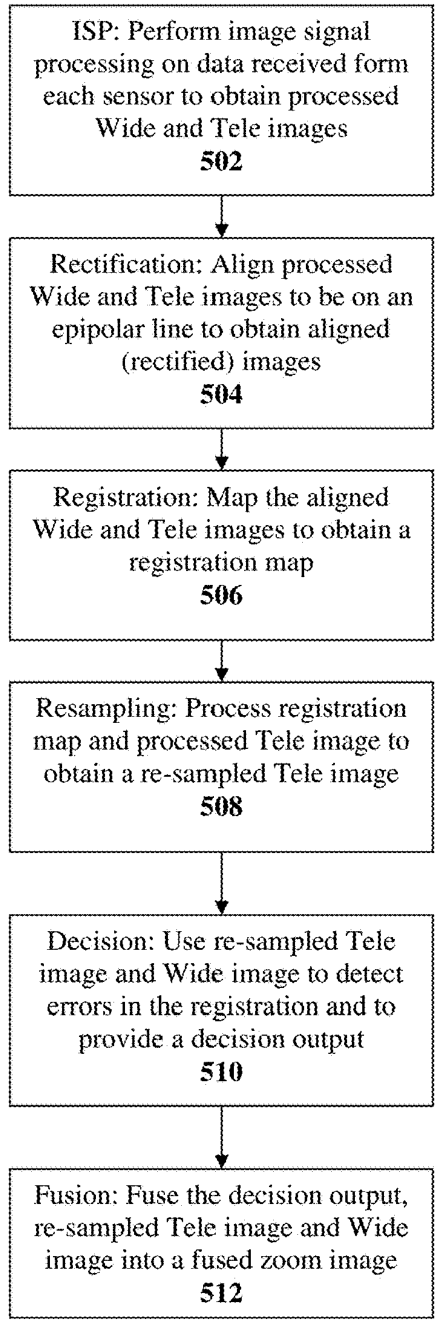

ISP: Perform image signal processing on data received form each sensor to obtain processed Wide and Tele images
502
Rectification: Align processed Wide and Tele images to be on an epipolar line to obtain aligned (rectified) images
504
Registration: Map the aligned Wide and Tele images to obtain a registration map
506
Resampling: Process registration map and processed Tele image to obtain a re-sampled Tele image
508
Decision: Use re-sampled Tele image and Wide image to detect errors in the registration and to provide a decision output
510
Fusion: Fuse the decision output, re-sampled Tele image and Wide image into a fused zoom image
512

FIG. 5

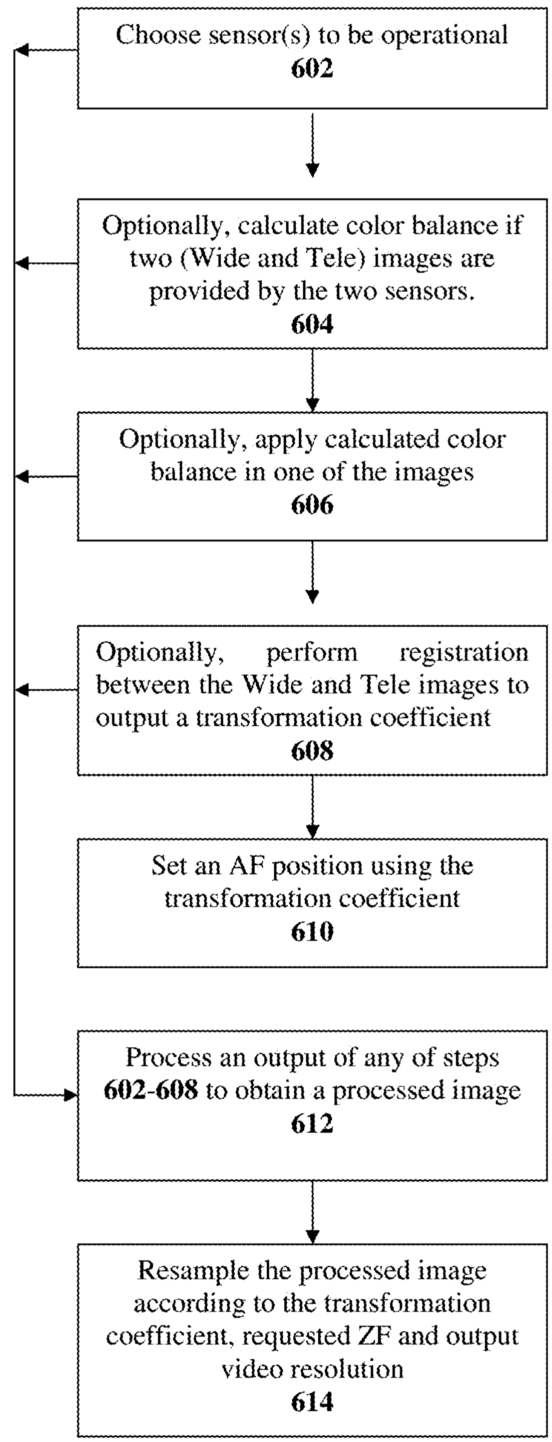
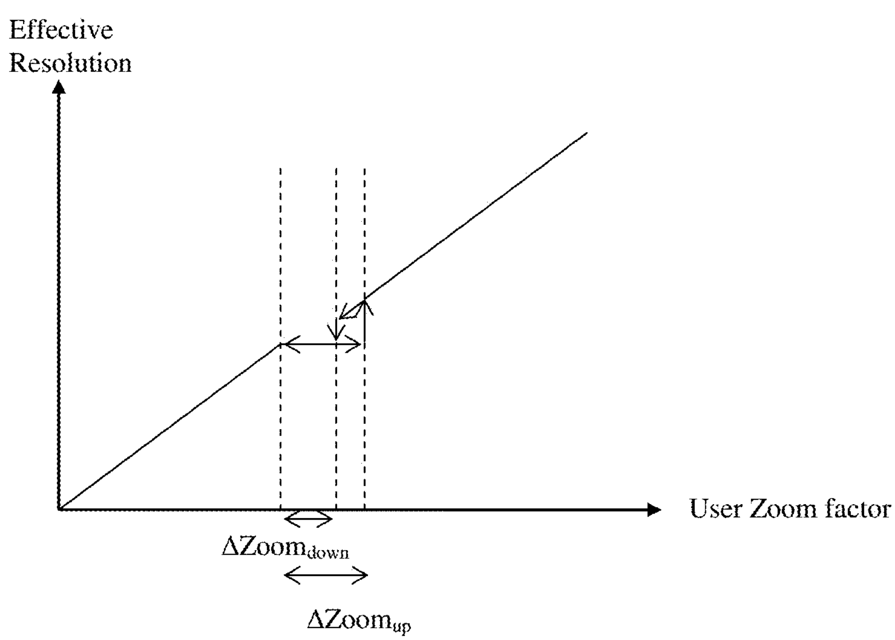

Choose sensor(s) to be operational
602
Optionally, calculate color balance if two (Wide and Tele) images are provided by the two sensors.
604
Optionally, apply calculated color balance in one of the images
606
Optionally, perform registration between the Wide and Tele images to output a transformation coefficient
608
Set an AF position using the transformation coefficient
610
Process an output of any of steps 602-608 to obtain a processed image
612
Resample the processed image according to the transformation coefficient, requested ZF and output video resolution
614

FIG. 6



Effective
Resolution
User Zoom factor
$\Delta Zoom_{down}$
$\Delta Zoom_{up}$

FIG. 7

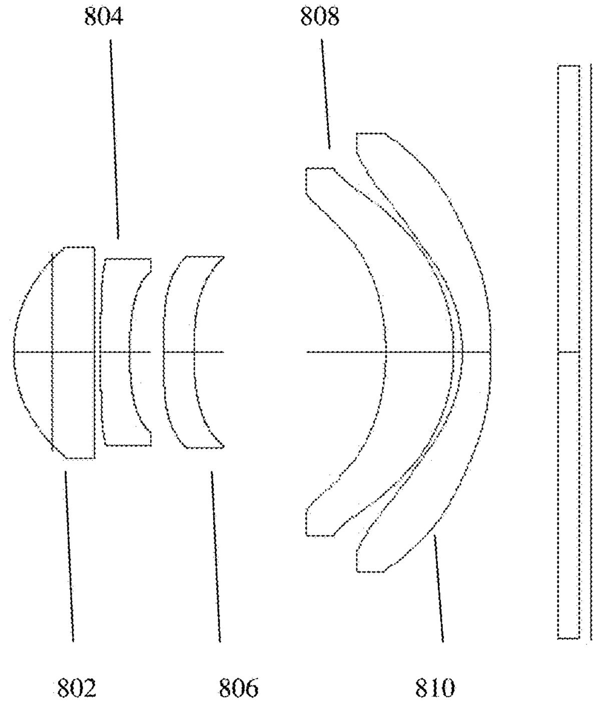


FIG. 8

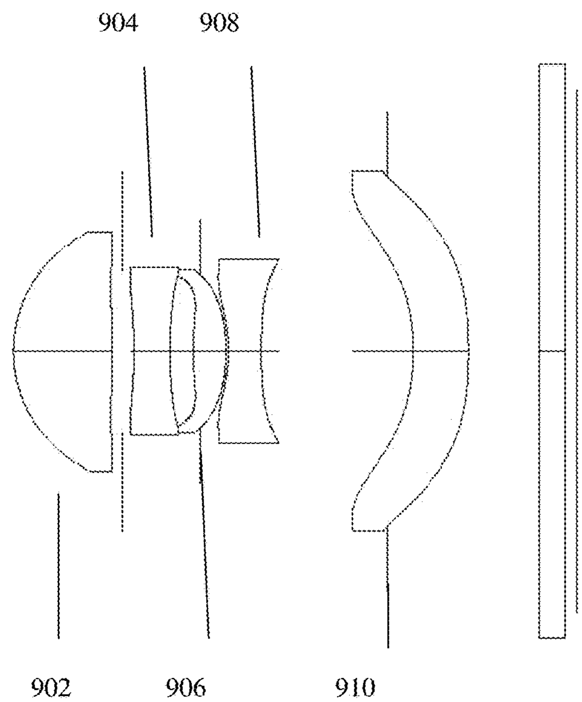


FIG. 9

DUAL APERTURE ZOOM DIGITAL CAMERA

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a Continuation application of U.S. patent application Ser. No. 15/865,869, filed Jan. 9, 2018, which was a Continuation application of U.S. patent application Ser. No. 15/424,853 filed Feb. 5, 2017, which was a Continuation application of U.S. patent application Ser. No. 14/880,251 filed Oct. 11, 2015 (issued as U.S. Pat. No. 9,661,233), which was a Continuation application of U.S. patent application Ser. No. 14/365,711 filed Jun. 16, 2014 (issued as U.S. Pat. No. 9,185,291), which was a 371 application from international patent application PCT/IB2014/062180 filed Jun. 12, 2014, and is related to and claims priority from U.S. Provisional Patent Application No. 61/834,486 having the same title and filed Jun. 13, 2013, which is incorporated herein by reference in its entirety.

FIELD

Embodiments disclosed herein relate in general to digital cameras and in particular to thin zoom digital cameras with both still image and video capabilities

BACKGROUND

Digital camera modules are currently being incorporated into a variety of host devices. Such host devices include cellular telephones, personal data assistants (PDAs), computers, and so forth. Consumer demand for digital camera modules in host devices continues to grow.

Host device manufacturers prefer digital camera modules to be small, so that they can be incorporated into the host device without increasing its overall size. Further, there is an increasing demand for such cameras to have higher-performance characteristics. One such characteristic possessed by many higher-performance cameras (e.g., standalone digital still cameras) is the ability to vary the focal length of the camera to increase and decrease the magnification of the image. This ability, typically accomplished with a zoom lens, is known as optical zooming. "Zoom" is commonly understood as a capability to provide different magnifications of the same scene and/or object by changing the focal length of an optical system, with a higher level of zoom associated with greater magnification and a lower level of zoom associated with lower magnification. Optical zooming is typically accomplished by mechanically moving lens elements relative to each other. Such zoom lenses are typically more expensive, larger and less reliable than fixed focal length lenses. An alternative approach for approximating the zoom effect is achieved with what is known as digital zooming. With digital zooming, instead of varying the focal length of the lens, a processor in the camera crops the image and interpolates between the pixels of the captured image to create a magnified but lower-resolution image.

Attempts to use multi-aperture imaging systems to approximate the effect of a zoom lens are known. A multi-aperture imaging system (implemented for example in a digital camera) includes a plurality of optical sub-systems (also referred to as "sub-cameras"). Each sub-camera includes one or more lenses and/or other optical elements which define an aperture such that received electro-magnetic radiation is imaged by the optical sub-system and a resulting image is directed towards a two-dimensional (2D) pixelated

image sensor region. The image sensor (or simply "sensor") region is configured to receive the image and to generate a set of image data based on the image. The digital camera may be aligned to receive electromagnetic radiation associated with scenery having a given set of one or more objects. The set of image data may be represented as digital image data, as well known in the art. Hereinafter in this description, "image" "image data" and "digital image data" may be used interchangeably. Also, "object" and "scene" may be used interchangeably.

Multi-aperture imaging systems and associated methods are described for example in US Patent Publications No. 2008/0030592, 2010/0277619 and 2011/0064327. In US 2008/0030592, two sensors are operated simultaneously to capture an image imaged through an associated lens. A sensor and its associated lens form a lens/sensor combination. The two lenses have different focal lengths. Thus, even though each lens/sensor combination is aligned to look in the same direction, each captures an image of the same subject but with two different fields of view (FOVs). One sensor is commonly called "Wide" and the other "Tele". Each sensor provides a separate image, referred to respectively as "Wide" (or "W") and "Tele" (or "T") images. A W-image reflects a wider FOV and has lower resolution than the T-image. The images are then stitched (fused) together to form a composite ("fused") image. In the composite image, the central portion is formed by the relatively higher-resolution image taken by the lens/sensor combination with the longer focal length, and the peripheral portion is formed by a peripheral portion of the relatively lower-resolution image taken by the lens/sensor combination with the shorter focal length. The user selects a desired amount of zoom and the composite image is used to interpolate values from the chosen amount of zoom to provide a respective zoom image. The solution offered by US 2008/0030592 requires, in video mode, very large processing resources in addition to high frame rate requirements and high power consumption (since both cameras are fully operational).

US 2010/0277619 teaches a camera with two lens/sensor combinations, the two lenses having different focal lengths, so that the image from one of the combinations has a FOV approximately 2-3 times greater than the image from the other combination. As a user of the camera requests a given amount of zoom, the zoomed image is provided from the lens/sensor combination having a FOV that is next larger than the requested FOV. Thus, if the requested FOV is less than the smaller FOV combination, the zoomed image is created from the image captured by that combination, using cropping and interpolation if necessary. Similarly, if the requested FOV is greater than the smaller FOV combination, the zoomed image is created from the image captured by the other combination, using cropping and interpolation if necessary. The solution offered by US 2010/0277619 leads to parallax artifacts when moving to the Tele camera in video mode.

In both US 2008/0030592 and US 2010/0277619, different focal length systems cause Tele and Wide matching FOVs to be exposed at different times using CMOS sensors. This degrades the overall image quality. Different optical F numbers ("F#") cause image intensity differences. Working with such a dual sensor system requires double bandwidth support, i.e. additional wires from the sensors to the following HW component. Neither US 2008/0030592 nor US 2010/0277619 deal with registration errors. Neither US2008/000592 nor US 2010/0277619 refer to partial fusion, i.e. fusion of less than all the pixels of both Wide and Tele images in still mode.

US 2011/0064327 discloses multi-aperture imaging systems and methods for image data fusion that include providing first and second sets of image data corresponding to an imaged first and second scene respectively. The scenes overlap at least partially in an overlap region, defining a first collection of overlap image data as part of the first set of image data, and a second collection of overlap image data as part of the second set of image data. The second collection of overlap image data is represented as a plurality of image data sub-cameras such that each of the sub-cameras is based on at least one characteristic of the second collection, and each sub-camera spans the overlap region. A fused set of image data is produced by an image processor, by modifying the first collection of overlap image data based on at least a selected one of, but less than all of, the image data sub-cameras. The systems and methods disclosed in this application deal solely with fused still images.

None of the known art references provide a thin (e.g. fitting in a cell-phone) dual-aperture zoom digital camera with fixed focal length lenses, the camera configured to operate in both still mode and video mode to provide still and video images, wherein the camera configuration uses partial or full fusion to provide a fused image in still mode and does not use any fusion to provide a continuous, smooth zoom in video mode.

Therefore there is a need for, and it would be advantageous to have thin digital cameras with optical zoom operating in both video and still mode that do not suffer from commonly encountered problems and disadvantages, some of which are listed above.

SUMMARY

Embodiments disclosed herein teach the use of dual-aperture (also referred to as dual-lens or two-sensor) optical zoom digital cameras. The cameras include two sub-cameras, a Wide sub-camera and a Tele sub-camera, each sub-camera including a fixed focal length lens, an image sensor and an image signal processor (ISP). The Tele sub-camera is the higher zoom sub-camera and the Wide sub-camera is the lower zoom sub-camera. In some embodiments, the lenses are thin lenses with short optical paths of less than about 9 mm. In some embodiments, the thickness/effective focal length (EFL) ratio of the Tele lens is smaller than about 1. The image sensor may include two separate 2D pixelated sensors or a single pixelated sensor divided into at least two areas. The digital camera can be operated in both still and video modes. In still mode, zoom is achieved "with fusion" (full or partial), by fusing W and T images, with the resulting fused image including always information from both W and T images. Partial fusion may be achieved by not using fusion in image areas where the Tele image is not focused. This advantageously reduces computational requirements (e.g. time).

In video mode, optical zoom is achieved "without fusion", by switching between the W and T images to shorten computational time requirements, thus enabling high video rate. To avoid discontinuities in video mode, the switching includes applying additional processing blocks, which include image scaling and shifting.

In order to reach optical zoom capabilities, a different magnification image of the same scene is captured (grabbed) by each camera sub-camera, resulting in FOV overlap between the two sub-cameras. Processing is applied on the two images to fuse and output one fused image in still mode. The fused image is processed according to a user zoom factor request. As part of the fusion procedure, up-sampling may be applied on one or both of the grabbed images to scale it to the image grabbed by the Tele sub-camera or to a scale defined by the user. The fusion or up-sampling may be applied to only some of the pixels of a sensor. Down-sampling can be performed as well if the output resolution is smaller than the sensor resolution.

The cameras and associated methods disclosed herein address and correct many of the problems and disadvantages of known dual-aperture optical zoom digital cameras. They provide an overall zoom solution that refers to all aspects: optics, algorithmic processing and system hardware (HW). The proposed solution distinguishes between video and still mode in the processing flow and specifies the optical requirements and HW requirements. In addition, it provides an innovative optical design that enables a low TTL/EFL ratio using a specific lens curvature order.

Due to the large focal length, objects that are in front or behind the plane of focus appear very blurry, and a nice foreground-to-background contrast is achieved. However, it is difficult to create such a blur using a compact camera with a relatively short focal length and small aperture size, such as a cell-phone camera. In some embodiments, a dual-aperture zoom system disclosed herein can be used to capture a shallow DOF photo (shallow compared with a DOF of a Wide camera alone), by taking advantage of the longer focal length of the Tele lens. The reduced DOF effect provided by the longer Tele focal length can be further enhanced in the final image by fusing data from an image captured simultaneously with the Wide lens. Depending on the distance to the object, with the Tele lens focused on a subject of the photo, the Wide lens can be focused to a closer distance than the subject so that objects behind the subject appear very blurry. Once the two images are captured, information from the out-of-focus blurred background in the Wide image is fused with the original Tele image background information, providing a blurrier background and even shallower DOF.

In an embodiment there is provided a zoom digital camera comprising a Wide imaging section that includes a fixed focal length Wide lens with a Wide FOV, a Wide sensor and a Wide image signal processor (ISP), the Wide imaging section operative to provide Wide image data of an object or scene; a Tele imaging section that includes a fixed focal length Tele lens with a Tele FOV that is narrower than the Wide FOV, a Tele sensor and a Tele ISP, the Tele imaging section operative to provide Tele image data of the object or scene; and a camera controller operatively coupled to the Wide and Tele imaging sections, the camera controller configured to combine in still mode at least some of the Wide and Tele image data to provide a fused output image of the object or scene from a particular point of view (POV), and to provide without fusion continuous zoom video mode output images of the object or scene, a camera controller operatively coupled to the Wide and Tele imaging sections, the camera controller configured to combine in still mode at least some of the Wide and Tele image data to provide a fused output image of the object or scene from a particular point of view and to provide without fusion continuous zoom video mode output images of the object or scene, each output image having a respective output resolution, wherein the video output images are provided with a smooth transition when switching between a lower zoom factor (ZF) value and a higher ZF value or vice versa, wherein at the lower ZF value the output resolution is determined by the Wide sensor, and wherein at the higher ZF value the output resolution is determined by the Tele sensor.

In an embodiment, the camera controller configuration to provide video output images with a smooth transition when switching between a lower ZF value and a higher ZF value or vice versa includes a configuration that uses at high ZF secondary information from the Wide camera and uses at low ZF secondary information from the Tele camera. As used herein, "secondary information" refers to white balance gain, exposure time, analog gain and color correction matrix.

In a dual-aperture camera image plane, as seen by each sub-camera (and respective image sensor), a given object will be shifted and have different perspective (shape). This is referred to as point-of-view (POV). The system output image can have the shape and position of either sub-camera image or the shape or position of a combination thereof. If the output image retains the Wide image shape then it has the Wide perspective POV. If it retains the Wide camera position then it has the Wide position POV. The same applies for Tele images position and perspective. As used in this description, the perspective POV may be of the Wide or Tele sub-cameras, while the position POV may shift continuously between the Wide and Tele sub-cameras. In fused images, it is possible to register Tele image pixels to a matching pixel set within the Wide image pixels, in which case the output image will retain the Wide POV ("Wide fusion"). Alternatively, it is possible to register Wide image pixels to a matching pixel set within the Tele image pixels, in which case the output image will retain the Tele POV ("Tele fusion"). It is also possible to perform the registration after either sub-camera image is shifted, in which case the output image will retain the respective Wide or Tele perspective POV.

In an embodiment there is provided a method for obtaining zoom images of an object or scene in both still and video modes using a digital camera, the method comprising the steps of providing in the digital camera a Wide imaging section having a Wide lens with a Wide FOV, a Wide sensor and a Wide image signal processor (ISP), a Tele imaging section having a Tele lens with a Tele FOV that is narrower than the Wide FOV, a Tele sensor and a Tele ISP, and a camera controller operatively coupled to the Wide and Tele imaging sections; and configuring the camera controller to combine in still mode at least some of the Wide and Tele image data to provide a fused output image of the object or scene from a particular point of view, and to provide without fusion continuous zoom video mode output images of the object or scene, each output image having a respective output resolution, wherein the video mode output images are provided with a smooth transition when switching between a lower ZF value and a higher ZF value or vice versa, and wherein at the lower ZF value the output resolution is determined by the Wide sensor while at the higher ZF value the output resolution is determined by the Tele sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting examples of embodiments disclosed herein are described below with reference to figures attached hereto that are listed following this paragraph. The drawings and descriptions are meant to illuminate and clarify embodiments disclosed herein, and should not be considered limiting in any way.

FIG. **1**A shows schematically a block diagram illustrating a dual-aperture zoom imaging system disclosed herein;

FIG. **1**B is a schematic mechanical diagram of the dual-aperture zoom imaging system of FIG. **1**A:

FIG. **2** shows an example of Wide sensor, Tele sensor and their respective FOVs;

FIG. **3** shows a schematically embodiment of CMOS sensor image grabbing vs. time;

FIG. **4** shows schematically a sensor time configuration which enables sharing one sensor interface using dual sensor zoom system;

FIG. **5** shows an embodiment of a method disclosed herein for acquiring a zoom image in capture mode;

FIG. **6** shows an embodiment of a method disclosed herein for acquiring a zoom image in video/preview mode;

FIG. **7** shows a graph illustrating an effective resolution zoom factor;

FIG. **8** shows one embodiment of a lens block in a thin camera disclosed herein;

FIG. **9** shows another embodiment of a lens block in a thin camera disclosed herein.

DETAILED DESCRIPTION

FIG. **1**A shows schematically a block diagram illustrating an embodiment of a dual-aperture zoom imaging system (also referred to simply as "digital camera" or "camera") disclosed herein and numbered **100**. Camera **100** comprises a Wide imaging section ("sub-camera") that includes a Wide lens block **102**, a Wide image sensor **104** and a Wide image processor **106**. Camera **100** further comprises a Tele imaging section ("sub-camera") that includes a Tele lens block **108**, a Tele image sensor **110** and a Tele image processor **112**. The image sensors may be physically separate or may be part of a single larger image sensor. The Wide sensor pixel size can be equal to or different from the Tele sensor pixel size. Camera **100** further comprises a camera fusion processing core (also referred to as "controller") **114** that includes a sensor control module **116**, a user control module **118**, a video processing module **126** and a capture processing module **128**, all operationally coupled to sensor control block **110**. User control module **118** comprises an operational mode function **120**, a region of interest (ROI) function **122** and a zoom factor (ZF) function **124**.

Sensor control module **116** is connected to the two sub-cameras and to the user control module **118** and used to choose, according to the zoom factor, which of the sensors is operational and to control the exposure mechanism and the sensor readout. Mode choice function **120** is used for choosing capture/video modes. ROI function **122** is used to choose a region of interest. As used herein, "ROI" is a user defined as a sub-region of the image that may be exemplarily 4% or less of the image area. The ROI is the region on which both sub-cameras are focused on. Zoom factor function **124** is used to choose a zoom factor. Video processing module **126** is connected to mode choice function **120** and used for video processing. Still processing module **128** is connected to the mode choice function **120** and used for high image quality still mode images. The video processing module is applied when the user desires to shoot in video mode. The capture processing module is applied when the user wishes to shoot still pictures.

FIG. **1**B is a schematic mechanical diagram of the dual-aperture zoom imaging system of FIG. **1**A. Exemplary dimensions: Wide lens TTL=4.2 mm and EFL=3.5 mm; Tele lens TTL=6 mm and EFL=7 mm; both Wide and Tele sensors ⅓ inch. External dimensions of Wide and Tele cameras: width (w) and length (l)=8.5 mm and height (h)=6.8 mm Distance "d" between camera centers=10 mm.

Following is a detailed description and examples of different methods of use of camera **100**.

Design for Continuous and Smooth Zoom in Video Mode

In an embodiment, in order to reach high quality continuous and smooth optical zooming in video camera mode while reaching real optical zoom using fixed focal length sub-cameras, the system is designed according to the following rules (Equations 1-3):

$$\mathrm{Tan}(\mathrm{FOV}_{Wide})/\mathrm{Tan}(\mathrm{FOV}_{Tele})=PL_{Wide}/PL_{video} \qquad (1)$$

where Tan refers to "tangent", while FOV_{Wide} and FOV_{Tele} refer respectively to the Wide and Tele lens fields of view (in degrees). As used herein, the FOV is measured from the center axis to the corner of the sensor (i.e. half the angle of the normal definition). PL_{Wide} and PL_{video} refer respectively to the "in-line" (i.e. in a line) number of Wide sensor pixels and in-line number of output video format pixels. The ratio $\mathrm{PL}_{Wide}/\mathrm{PL}_{video}$ is called an "oversampling ratio". For example, in order to get full and continuous optical zoom experience with a 12 Mp sensor (sensor dimensions 4000×3000) and a required 1080p (dimension 1920×1080) video format, the FOV ratio should be 4000/1920=2.083. Moreover, if the Wide lens FOV is given as FOV_{Wide}=37.5°, the required Tele lens FOV is 20.2° The zoom switching point is set according to the ratio between sensor pixels in-line and the number of pixels in-line in the video format and defined as:

$$Z_{switch}=PL_{Wide}/PL_{video} \qquad (2)$$

Maximum optical zoom is reached according to the following formula:

$$Z_{max}=\mathrm{Tan}(\mathrm{FOV}_{Wide})/\mathrm{Tan}(\mathrm{FOV}_{Tele})*PL_{Tele}/PL_{video} \qquad (3)$$

For example: for the configuration defined above and assuming PL_{Tele}=4000 and PL_{video}=1920, Z_{max}=4.35.

In an embodiment, the sensor control module has a setting that depends on the Wide and Tele FOVs and on a sensor oversampling ratio, the setting used in the configuration of each sensor. For example, when using a 4000×3000 sensor and when outputting a 1920×1080 image, the oversampling ratio is 4000/1920=2.0833.

In an embodiment, the Wide and Tele FOVs and the oversampling ratio satisfy the condition

$$0.8*PL_{Wide}/PL_{video}<\mathrm{Tan}(\mathrm{FOV}_{Wide})/\mathrm{Tan}(\mathrm{FOV}_{Tele})<1.2*PL_{Wide}/PL_{video}. \qquad (4)$$

Still Mode Operation/Function

In still camera mode, the obtained image is fused from information obtained by both sub-cameras at all zoom levels, see FIG. **2**, which shows a Wide sensor **202** and a Tele sensor **204** and their respective FOVs. Exemplarily, as shown, the Tele sensor FOV is half the Wide sensor FOV. The still camera mode processing includes two stages: (1) setting HW settings and configuration, where a first objective is to control the sensors in such a way that matching FOVs in both images (Tele and Wide) are scanned at the same time. A second objective is to control the relative exposures according to the lens properties. A third objective is to minimize the required bandwidth from both sensors for the ISPs; and (2) image processing that fuses the Wide and the Tele images to achieve optical zoom, improves SNR and provides wide dynamic range.

FIG. **3** shows image line numbers vs. time for an image section captured by CMOS sensors. A fused image is obtained by line (row) scans of each image. To prevent matching FOVs in both sensors to be scanned at different times, a particular configuration is applied by the camera controller on both image sensors while keeping the same frame rate. The difference in FOV between the sensors determines the relationship between the rolling shutter time and the vertical blanking time for each sensor. In the particular configuration, the scanning is synchronized such that the same points of the object in each view are obtained simultaneously.

Specifically with reference to FIG. **3** and according to an embodiment of a method disclosed herein, the configuration to synchronize the scanning includes: setting the Tele sensor vertical blanking time VB_{Tele} to equal the Wide sensor vertical blanking time VB_{Wide} plus half the Wide sensor rolling shutter time RST_{Wide}; setting the Tele and Wide sensor exposure times ET_{Tele} and ET_{Wide} to be equal or different; setting the Tele sensor rolling shutter time RST_{Tele} to be $0.5*\mathrm{RST}_{Wide}$; and setting the frame rates of the two sensors to be equal. This procedure results in identical image pixels in the Tele and Wide sensor images being exposed at the same time

In another embodiment, the camera controller synchronizes the Wide and Tele sensors so that for both sensors the rolling shutter starts at the same time.

The exposure times applied to the two sensors could be different, for example in order to reach same image intensity using different F# and different pixel size for the Tele and Wide systems. In this case, the relative exposure time may be configured according to the formula below:

$$ET_{Tele}=ET_{Wide}\cdot(F\#_{Tele}/F\#_{Wide})^2\cdot(\mathrm{Pixel\ size}_{Wide}/\mathrm{Pixel\ size}_{Tele})^2 \qquad (5)$$

Other exposure time ratios may be applied to achieve wide dynamic range and improved SNR. Fusing two images with different intensities will result in wide dynamic range image.

In more detail with reference to FIG. **3**, in the first stage, after the user chooses a required zoom factor ZF, the sensor control module configures each sensor as follows:

1) Cropping Index Wide Sensor:

$$Y_{Wide\ start}=\tfrac{1}{2}\cdot PC_{Wide}(1-1/ZF))$$

$$Y_{Wide\ end}=\tfrac{1}{2}\cdot PC_{Wide}(1+1/ZF)$$

where PC is the number of pixels in a column, and Y is the row number

2) Cropping Index Tele Sensor:

If ZF>Tan (FOV_{Wide})/Tan (FOV_{Tele}), then

$$Y_{Tele\ start}=\tfrac{1}{2}\cdot PC_{Tele}(1-(1/ZF)\cdot\mathrm{Tan}(\mathrm{FOV}_{Tele})/\mathrm{Tan}(\mathrm{FOV}_{Wide}))$$

$$Y_{Tele\ end}=\tfrac{1}{2}\cdot PC_{Tele}(1+(1/ZF)\cdot\mathrm{Tan}(\mathrm{FOV}_{Tele})/\mathrm{Tan}(\mathrm{FOV}_{Wide}))$$

If ZF<Tan (FOV_{Wide})/Tan (FOV_{Tele}), then

$$Y_{Tele\ start}=0$$

$$Y_{Tele\ end}=PC_{Tele}$$

This will result in an exposure start time of the Tele sensor with a delay of (in numbers of lines, relative to the Wide sensor start time):

$$(1-ZF/((\mathrm{Tan}(\mathrm{FOV}_{Wide})/\mathrm{Tan}(\mathrm{FOV}_{Tele})))\cdot 1/(2\cdot\mathrm{FPS}) \qquad (6)$$

where FPS is the sensor's frame per second configuration. In cases where ZF>Tan (FOV_{Wide})/Tan (FOV_{Tele}), no delay will be introduced between Tele and Wide exposure starting point. For example, for a case where Tan (FOV_{Wide})/Tan (FOV_{Tele})=2 and ZF=1, the Tele image first pixel is exposed ¼·(1/FPS) second after the Wide image first pixel was exposed.

After applying the cropping according to the required zoom factor, the sensor rolling shutter time and the vertical blank should be configured in order to satisfy the equation to keep the same frame rate:

$$VB_{Wide}+RST_{Wide}=VB_{Tele}+RST_{Tele} \quad (7)$$

FIG. **3** exemplifies Eq. (7), One way to satisfy Eq. (7) is to increase the RST_{Wide}. Controlling the RST_{Wide} may be done by changing the horizontal blanking (HB) of the Wide sensor. This will cause a delay between the data coming out from each row of the Wide sensor.

Generally, working with a dual-sensor system requires multiplying the bandwidth to the following block, for example the ISP. For example, using 12 Mp working at 30 fps, 10 bit per pixel requires working at 3.6 Gbit/sec. In this example, supporting this bandwidth requires 4 lanes from each sensor to the respective following ISP in the processing chain. Therefore, working with two sensors requires double bandwidth (7.2 Gbit/sec) and 8 lanes connected to the respective following blocks. The bandwidth can be reduced by configuring and synchronizing the two sensors. Consequently, the number of lanes can be half that of a conventional configuration (3.6 Gbit/sec).

FIG. **4** shows schematically a sensor time configuration that enables sharing one sensor interface using a dual-sensor zoom system, while fulfilling the conditions in the description of FIG. **3** above. For simplicity, assuming the Tele sensor image is magnified by a factor of 2 compared with the Wide sensor image, the Wide sensor horizontal blanking time HB_{Wide} is set to twice the Wide sensor line readout time. This causes a delay between output Wide lines. This delay time matches exactly the time needed to output two lines from the Tele sensor. After outputting two lines from the Tele sensor, the Tele sensor horizontal blanking time HB_{Tele} is set to be one Wide line readout time, so, while the Wide sensor outputs a row from the sensor, no data is being output from the Tele sensor. For this example, every 3^{rd} line in the Tele sensor is delayed by an additional HB_{Tele}. In this delay time, one line from the Wide sensor is output from the dual-sensor system. After the sensor configuration stage, the data is sent in parallel or by using multiplexing into the processing section.

FIG. **5** shows an embodiment of a method disclosed herein for acquiring a zoom image in still mode. In ISP step **502**, the data of each sensor is transferred to the respective ISP component, which performs on the data various processes such as denoising, demosaicing, sharpening, scaling, etc, as known in the art. After the processing in step **502**, all following actions are performed in capture processing core **128**: in rectification step **504**, both Wide and Tele images are aligned to be on the epipolar line; in registration step **506**, mapping between the Wide and the Tele aligned images is performed to produce a registration map; in resampling step **508**, the Tele image is resampled according to the registration map, resulting in a re-sampled Tele image; in decision step **510**, the re-sampled Tele image and the Wide image are processed to detect errors in the registration and to provide a decision output. In more detail, in step **510**, the re-sampled Tele image data is compared with the Wide image data and if the comparison detects significant dissimilarities, an error is indicated. In this case, the Wide pixel values are chosen to be used in the output image. Then, in fusion step **512**, the decision output, re-sampled Tele image and the Wide image are fused into a single zoom image.

To reduce processing time and power, steps **506**, **508**, **510**, **512** could be bypassed by not fusing the images in non-focused areas. In this case, all steps specified above should be applied on focused areas only. Since the Tele optical system will introduce shallower depth of field than the Wide optical system, defocused areas will suffer from lower contrast in the Tele system.

Zoom-In and Zoom-Out in Still Camera Mode

We define the following: TFOV=tan (camera FOV/2). "Low ZF" refers to all ZF that comply with ZF<Wide TFOV/Tele TFOV. "High ZF" refers to all ZF that comply with ZF>Wide TFOV/Tele TFOV. "ZFT" refers to a ZF that complies with ZF=Wide TFOV/Tele TFOV. In one embodiment, zoom-in and zoom-out in still mode is performed as follows:

Zoom-in: at low ZF up to slightly above ZFT, the output image is a digitally zoomed, Wide fusion output. For the up-transfer ZF, the Tele image is shifted and corrected by global registration (GR) to achieve smooth transition. Then, the output is transformed to a Tele fusion output. For higher (than the up-transfer) ZF, the output is the Tele fusion output digitally zoomed.

Zoom-out: at high ZF down to slightly below ZFT, the output image is a digitally zoomed, Tele fusion output. For the down-transfer ZF, the Wide image is shifted and corrected by GR to achieve smooth transition. Then, the output is transformed to a Wide fusion output. For lower (than the down-transfer) ZF, the output is basically the down-transfer ZF output digitally zoomed but with gradually smaller Wide shift correction, until for ZF=1 the output is the unchanged Wide camera output.

In another embodiment, zoom-in and zoom-out in still mode is performed as follows:

Zoom-in: at low ZF up to slightly above ZFT, the output image is a digitally zoomed, Wide fusion output. For the up-transfer ZF and above, the output image is the Tele fusion output.

Zoom-out: at high ZF down to slightly below ZFT, the output image is a digitally zoomed, Tele fusion output. For the down-transfer ZF and below, the output image is the Wide fusion output.

Video Mode Operation/Function

Smooth Transition

When a dual-aperture camera switches the camera output between sub-cameras or points of view, a user will normally see a "jump" (discontinuous) image change. However, a change in the zoom factor for the same camera and POV is viewed as a continuous change. A "smooth transition" is a transition between cameras or POVs that minimizes the jump effect. This may include matching the position, scale, brightness and color of the output image before and after the transition. However, an entire image position matching between the sub-camera outputs is in many cases impossible, because parallax causes the position shift to be dependent on the object distance. Therefore, in a smooth transition as disclosed herein, the position matching is achieved only in the ROI region while scale brightness and color are matched for the entire output image area.

Zoom-In and Zoom-Out in Video Mode

In video mode, sensor oversampling is used to enable continuous and smooth zoom experience. Processing is applied to eliminate the changes in the image during cross-over from one sub-camera to the other. Zoom from 1 to Z_{switch} is performed using the Wide sensor only. From Z_{switch} and on, it is performed mainly by the Tele sensor. To prevent "jumps" (roughness in the image), switching to the Tele image is done using a zoom factor which is a bit higher ($Z_{switch}+\Delta Zoom$) than Z_{switch}. $\Delta Zoom$ is determined according to the system's properties and is different for cases where zoom-in is applied and cases where zoom-out is applied ($\Delta Zoom_{in} \neq \Delta Zoom_{out}$). This is done to prevent residual jumps artifacts to be visible at a certain zoom factor. The switching between sensors, for an increasing zoom and for decreasing zoom, is done on a different zoom factor.

The zoom video mode operation includes two stages: (1) sensor control and configuration, and (2) image processing. In the range from 1 to Z_{switch}, only the Wide sensor is operational, hence, power can be supplied only to this sensor. Similar conditions hold for a Wide AF mechanism. From $Z_{switch}+\Delta Zoom$ to Z_{max} only the Tele sensor is operational, hence, power is supplied only to this sensor. Similarly, only the Tele sensor is operational and power is supplied only to it for a Tele AF mechanism. Another option is that the Tele sensor is operational and the Wide sensor is working in low frame rate. From Z_{switch} to $Z_{switch}+\Delta Zoom$, both sensors are operational.

Zoom-in: at low ZF up to slightly above ZFT, the output image is the digitally zoomed, unchanged Wide camera output. For the up-transfer ZF, the output is a transformed Tele sub-camera output, where the transformation is performed by a global registration (GR) algorithm to achieve smooth transition. For higher (than the up-transfer), the output is the transfer ZF output digitally zoomed.

Zoom-out: at high ZF down to slightly below ZFT, the output image is the digitally zoomed transformed Tele camera output. For the down-transfer ZF, the output is a shifted Wide camera output, where the Wide shift correction is performed by the GR algorithm to achieve smooth transition, i.e. with no jump in the ROI region. For lower (than the down-transfer) ZF, the output is basically the down-transfer ZF output digitally zoomed but with gradually smaller Wide shift correction, until for ZF=1 the output is the unchanged Wide camera output.

FIG. **6** shows an embodiment of a method disclosed herein for acquiring a zoom image in video/preview mode for 3 different zoom factor (ZF) ranges: (a) ZF range=1: Z_{switch}; (b) ZF range=Z_{switch}: $Z_{switch}+\Delta Zoom_{in}$: and (c) Zoom factor range=$Z_{switch}+\Delta Zoom_{in}$: Z_{max}. The description is with reference to a graph of effective resolution vs. zoom value (FIG. **7**). In step **602**, sensor control module **116** chooses (directs) the sensor (Wide, Tele or both) to be operational. Specifically, if the ZF range=1:Z_{switch}, module **116** directs the Wide sensor to be operational and the Tele sensor to be non-operational. If the ZF range is Z_{switch}: $Z_{switch}+\Delta Zoom_{in}$, module **116** directs both sensors to be operational and the zoom image is generated from the Wide sensor. If the ZF range is $Z_{switch}+\Delta Zoom_{in}$:$Z_{max}$, module **116** directs the Wide sensor to be non-operational and the Tele sensor to be operational. After the sensor choice in step **602**, all following actions are performed in video processing core **126**. Optionally, in step **604**, color balance is calculated if two images are provided by the two sensors. Optionally yet, in step **606**, the calculated color balance is applied in one of the images (depending on the zoom factor). Further optionally, in step **608**, registration is performed between the Wide and Tele images to output a transformation coefficient. The transformation coefficient can be used to set an AF position in step **610**. In step **612**, an output of any of steps **602-608** is applied on one of the images (depending on the zoom factor) for image signal processing that may include denoising, demosaicing, sharpening, scaling, etc. In step **614**, the processed image is resampled according to the transformation coefficient, the requested ZF (obtained from zoom function **124**) and the output video resolution (for example 1080p). To avoid a transition point to be executed at the same ZF, ΔZoom can change while zooming in and while zooming out. This will result in hysteresis in the sensor switching point.

In more detail, for ZF range 1: Z_{switch}, for ZF<Z_{switch}, the Wide image data is transferred to the ISP in step **612** and resampled in step **614**. For ZF range=Z_{switch}: $Z_{switch}+\Delta Zoom_{in}$, both sensors are operational and the zoom image is generated from the Wide sensor. The color balance is calculated for both images according to a given ROI. In addition, for a given ROI, registration is performed between the Wide and Tele images to output a transformation coefficient. The transformation coefficient is used to set an AF position. The transformation coefficient includes the translation between matching points in the two images. This translation can be measured in a number of pixels. Different translations will result in a different number of pixel movements between matching points in the images. This movement can be translated into depth and the depth can be translated into an AF position. This enables to set the AF position by only analyzing two images (Wide & Tele). The result is fast focusing.

Both color balance ratios and transformation coefficient are used in the ISP step. In parallel, the Wide image is processed to provide a processed image, followed by resampling. For ZF range=$Z_{switch}+\Delta Zoom_{in}$:$Z_{max}$ and for Zoom factor >$Z_{switch}\Delta Zoom_{in}$, the color balance calculated previously is now applied on the Tele image. The Tele image data is transferred to the ISP in step **612** and resampled in step **614**. To eliminate crossover artifacts and to enable smooth transition to the Tele image, the processed Tele image is resampled according to the transformation coefficient, the requested ZF (obtained from zoom function **124**) and the output video resolution (for example 1080p).

FIG. **7** shows the effective resolution as a function of the zoom factor for a zoom-in case and for a zoom-out case $\Delta Zoom_{up}$ is set when we zoom in, and $\Delta Zoom_{down}$ is set when we zoom out. Setting $\Delta Zoom_{up}$ to be different from $\Delta Zoom_{down}$ will result in transition between the sensors to be performed at different zoom factor ("hysteresis") when zoom-in is used and when zoom-out is used. This hysteresis phenomenon in the video mode results in smooth continuous zoom experience.

Optical Design

Additional optical design considerations were taken into account to enable reaching optical zoom resolution using small total track length (TTL). These considerations refer to the Tele lens. In an embodiment, the camera is "thin" (see also FIG. **1**B) in the sense that is has an optical path of less than 9 mm and a thickness/focal length (FP) ratio smaller than about 0.85. Exemplarily, as shown in FIG. **8**, such a thin camera has a lens block that includes (along an optical axis starting from an object) five lenses: a first lens element **802** with positive power and two lenses **804** and **806** and with negative power, a fourth lens **808** with positive power and a fifth lens **810** with negative power. In the embodiment of FIG. **8**, the EFL is 7 mm, the TTL is 4.7 mm, f=6.12 and FOV=20°. Thus the Tele lens TTL/EFL ratio is smaller than 0.9. In other embodiments, the Tele lens TTL/EFL ratio may be smaller than 1.

In another embodiment of a lens block in a thin camera, shown in FIG. **9**, the camera has a lens block that includes (along an optical axis starting from an object) a first lens element **902** with positive power a second lens element **904** with negative power, a third lens element with positive power **906** and a fourth lens element with negative power **908**, and a fifth lens element **910** with positive or negative power. In this embodiment, f=7.14, F#=3.5, TTL=5.8 mm and FOV=22.7°.

In conclusion, dual aperture optical zoom digital cameras and associate methods disclosed herein reduce the amount of processing resources, lower frame rate requirements, reduce power consumption, remove parallax artifacts and provide continuous focus (or provide loss of focus) when changing

from Wide to Tele in video mode. They provide a dramatic reduction of the disparity range and avoid false registration in capture mode. They reduce image intensity differences and enable work with a single sensor bandwidth instead of two, as in known cameras.

All patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present disclosure.

While this disclosure has been described in terms of certain embodiments and generally associated methods, alterations and permutations of the embodiments and methods will be apparent to those skilled in the art. The disclosure is to be understood as not limited by the specific embodiments described herein, but only by the scope of the appended claims.

What is claimed is:

1. A dual-aperture digital camera for imaging an object or scene, comprising:

a) a Wide camera comprising a Wide lens and a Wide image sensor, the Wide camera having a respective field of view FOV_W and being operative to provide a Wide image of the object or scene;

b) a Tele camera comprising a Tele lens and a Tele image sensor, the Tele camera having a respective field of view FOV_T narrower than FOV_W and being operative to provide a Tele image of the object or scene, wherein the Tele lens has a respective effective focal length EFL_T and total track length TTL_T fulfilling the condition $EFL_T/TTL_T>1$;

c) a first autofocus (AF) mechanism coupled mechanically to, and used to perform an AF action on the Wide lens;

d) a second AF mechanism coupled mechanically to, and used to perform an AF action on the Tele lens; and

e) a camera controller operatively coupled to the first and second AF mechanisms and to the Wide and Tele image sensors and configured to control the AF mechanisms and to process the Wide and Tele images to create a fused image, wherein areas in the Tele image that are not focused are not combined with the Wide image to create the fused image and wherein the camera controller is further operative to output the fused image with a point of view (POV) of the Wide camera by mapping Tele image pixels to matching pixels within the Wide image.

2. The dual-aperture digital camera of claim **1**, wherein the camera controller is further configured to perform rectification of the Wide and Tele images by aligning these images to be on an approximately epipolar line to obtain rectified Wide and Tele images.

3. The dual-aperture digital camera of claim **2**, wherein the camera controller is further configured to perform mapping between the rectified Wide and Tele images to produce a registration map.

4. The dual-aperture digital camera of claim **3**, wherein the camera controller is further configured to perform resampling of the Tele image according to the registration map to provide a re-sampled Tele image.

5. The dual-aperture digital camera of claim **4**, wherein the camera controller is further configured to process the re-sampled Tele image and the Wide image to detect an error in the registration and to provide a decision output.

6. The dual-aperture digital camera of claim **5**, wherein, if an error is detected, the camera controller is further configured to choose Wide pixel values to be used in the output image for pixels that caused the error.

7. The dual-aperture digital camera of claim **6**, wherein the Wide and Tele image sensors have pixels with identical pixel counts and with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ wherein Pixel $size_{Wide}$ is equal to Pixel $size_{Tele}$, wherein the Wide and Tele lenses have different F numbers $F\#_{Wide}$ and $F\#_{Tele}$, and wherein the camera controller is further configured to synchronize the Wide and Tele image sensors to start exposure at the same time.

8. The dual-aperture digital camera of claim **6**, wherein the Wide and Tele image sensors have pixels with identical pixel counts and with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ wherein Pixel $size_{Wide}$ is not equal to Pixel $size_{Tele}$, wherein the Wide and Tele lenses have different F numbers $F\#_{Wide}$ and $F\#_{Tele}$, and wherein the camera controller is further configured to synchronize the Wide and Tele image sensors to start exposure at the same time.

9. The dual-aperture digital camera of claim **6**, wherein the Wide and Tele image sensors have pixels with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ and wherein Pixel $size_{Wide}$ is not equal to Pixel $size_{Tele}$, wherein the Wide and Tele lenses have different F numbers $F\#_{Wide}$ and $F\#_{Tele}$, and wherein the camera controller is further configured to synchronize the Wide and Tele image sensors to start exposure at the same time.

10. The dual-aperture digital camera of claim **1**, wherein the Wide and Tele image sensors have pixels with identical pixel counts.

11. The dual-aperture digital camera of claim **10**, wherein the pixel count is 12 MP.

12. The dual-aperture digital camera of claim **1**, wherein the Wide and Tele image sensors have pixels with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ and wherein Pixel $size_{Wide}$ is equal to Pixel $size_{Tele}$.

13. The dual-aperture digital camera of claim **1**, wherein the Wide and Tele image sensors have pixels with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ and wherein Pixel $size_{Wide}$ is not equal to Pixel $size_{Tele}$.

14. The dual-aperture digital camera of claim **1**, wherein the Wide and Tele lenses have different F numbers $F\#_{Wide}$ and $F\#_{Tele}$.

15. The dual-aperture digital camera of claim **14**, wherein the camera controller is further configured to synchronize scanning of the Wide and Tele image sensors such that matching FOVs in the Wide and Tele images are scanned at the same time.

16. The dual-aperture digital camera of claim **14**, wherein the camera controller is further configured to synchronize the Wide and Tele image sensors to start exposure at the same time.

17. The dual-aperture digital camera of claim **1**, wherein the Wide and Tele lenses have respective F numbers $F\#_{Wide}$ and $F\#_{Tele}$ and wherein the camera controller is further configured to set respective Wide and Tele image sensor exposure times ET_{Wide} and ET_{Tele} to fulfill the condition $ET_{Tele}=ET_{Wide}\times(F\#_{Tele}/F\#_{Wide})^2\times(\text{Pixel size}_{Wide}/\text{Pixel size}_{Tele})^2$.

18. The dual-aperture digital camera of claim **1**, wherein the Wide and Tele lenses have respective F numbers $F\#_{Wide}$ and $F\#_{Tele}$ and wherein the camera controller is further configured to set respective Wide and Tele image sensor exposure times ET_{Wide} and ET_{Tele} to be equal.

19. A dual-aperture digital camera for imaging an object or scene, comprising:

a) a Wide camera comprising a Wide lens and a Wide image sensor, the Wide camera having a respective field of view FOV_W and being operative to provide a Wide image of the object or scene;

b) a Tele camera comprising a Tele lens and a Tele image sensor, the Tele camera having a respective field of view FOV_T narrower than FOV_W and being operative to provide a Tele image of the object or scene, wherein the Tele lens has a respective effective focal length EFL_T and total track length TTL_T fulfilling the condition $EFL_T/TTL_T>1$;

c) a first autofocus (AF) mechanism coupled mechanically to, and used to perform an AF action on the Wide lens;

d) a second AF mechanism coupled mechanically to, and used to perform an AF action on the Tele lens, wherein the Wide and Tele lenses have different F numbers $F\#_{Wide}$ and $F\#_{Tele}$, wherein the Wide and Tele image sensors have pixels with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ wherein Pixel $size_{Wide}$ is not equal to Pixel $size_{Tele}$, and wherein the Tele camera has a Tele camera depth of field (DOF_T) shallower than a DOF of the Wide camera (DOF_W); and

e) a camera controller operatively coupled to the first and second AF mechanisms and to the Wide and Tele image sensors and configured to control the AF mechanisms, to process the Wide and Tele images to find translations between matching points in the images to calculate depth information and to create a fused image suited for portrait photos, the fused image having a DOF shallower than DOF_T and having a blurred background.

20. The dual-aperture digital camera of claim **19**, wherein the Tele lens includes five lens elements along an optical axis from an object side to an image side, starting from the object side with a first lens element with positive power, a second lens element with negative power, a fourth lens element with negative power and a fifth lens element, wherein the largest distance between consecutive lens elements along the optical axis is a distance between the fourth lens element and the fifth lens element.

21. The dual-aperture digital camera of claim **20**, wherein the fused image having a DOF shallower than DOF_T is output as a portrait photo similar to a portrait photo taken with a digital single-lens reflex (DSLR) camera.

22. The dual-aperture digital camera of claim **21**, wherein the DSLR has a focal length between 50-80 mm.

23. A method comprising:

a) providing a dual-camera comprising a Wide camera and a Tele camera, the Wide and Tele cameras having respective Wide and Tele lenses, Wide and Tele image sensors and Wide and Tele fields of view FOV_W and FOV_T, wherein FOV_T is narrower than FOV_W, wherein the Tele lens has a respective effective focal length EFL_T and total track length TTL_T fulfilling the condition $EFL_T/TTL_T>1$;

b) acquiring a Wide image with the Wide sensor and a Tele image with the Tele sensor;

c) processing the Wide and Tele images to create a fused image, wherein areas in the Tele image that are not focused are not combined with the Wide image to create the fused image; and

d) outputting the fused image with a point of view (POV) of the Wide camera by mapping Tele image pixels to matching pixels within the Wide image.

24. The method of claim **23**, further comprising rectifying the Wide and Tele images by aligning these images to be on an approximately epipolar line to obtain rectified Wide and Tele images.

25. The method of claim **24**, further comprising mapping between the rectified Wide and Tele images to produce a registration map.

26. The method of claim **25**, further comprising resampling the Tele image according to the registration map to provide a re-sampled Tele image.

27. The method of claim **26**, further comprising processing the re-sampled Tele image and the Wide image to detect an error in the registration and to provide a decision output.

28. The method of claim **27**, wherein if an error is detected, further comprising choosing Wide pixel values to be used in the output image for those pixels that caused the error.

29. The method of claim **28**, wherein the Wide and Tele image sensors have pixels with identical pixel counts and with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ wherein Pixel $size_{Wide}$ is equal to Pixel $size_{Tele}$ and wherein the Wide and Tele lenses have different F numbers $F\#_{Wide}$ and $F\#_{Tele}$, the method further comprising synchronizing the Wide and Tele image sensors to start exposure at the same time.

30. The method of claim **28**, wherein the Wide and Tele image sensors have pixels with identical pixel counts and with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ wherein Pixel $size_{Wide}$ is not equal to Pixel $size_{Tele}$ and wherein the Wide and Tele lenses have different F numbers $F\#_{Wide}$ and $F\#_{Tele}$, the method further comprising synchronizing the Wide and Tele image sensors to start exposure at the same time.

31. The method of claim **28**, wherein the Wide and Tele image sensors have pixels with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ wherein Pixel $size_{Wide}$ is not equal to Pixel $size_{Tele}$ and wherein the Wide and Tele lenses have different F numbers $F\#_{Wide}$ and $F\#_{Tele}$, the method further comprising synchronizing the Wide and Tele image sensors to start exposure at the same time.

32. The method of claim **23**, wherein the Wide and Tele image sensors have pixels with identical pixel counts.

33. The method of claim **32**, wherein the pixel count is 12 MP.

34. The method of claim **23**, wherein the Wide and Tele image sensors have pixels with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ and wherein Pixel $size_{Wide}$ is equal to Pixel $size_{Tele}$.

35. The method of claim **23**, wherein the Wide and Tele image sensors have pixels with respective pixel sizes Pixel $size_{Wide}$ and Pixel $size_{Tele}$ and wherein Pixel $size_{Wide}$ is not equal to Pixel $size_{Tele}$.

36. The method of claim **23**, wherein the Wide and Tele lenses have different F numbers $F\#_{Wide}$ and $F\#_{Tele}$.

37. The method of claim **36**, further comprising synchronizing scanning of the Wide and Tele image sensors such that matching FOVs in the Wide and Tele images are scanned at the same time.

38. The method of claim **36**, further comprising synchronizing the Wide and Tele image sensors to start exposure at the same time.

39. The method of claim **23**, wherein the Wide and Tele lenses have respective F numbers $F\#_{Wide}$ and $F\#_{Tele}$, the method further comprising setting respective Wide and Tele image sensor exposure times ET_{Wide} and ET_{Tele} to fulfill the condition $ET_{Tele}=ET_{Wide}\times(F\#_{Tele}/F\#_{Wide})^2\times(\text{Pixel size}_{Wide}/\text{Pixel size}_{Tele})^2$.

40. The method of claim **23**, wherein the Wide and Tele lenses have respective F numbers $F\#_{Wide}$ and $F\#_{Tele}$, the method further comprising setting respective Wide and Tele image sensor exposure times ET_{Wide} and ET_{Tele} to be equal.

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CERTIFICATE OF COMPLIANCE

The brief complies with the type-volume limitation of Fed. Cir. R. 32(b)(1) because this brief contains 13,920 words, excluding the parts of the brief exempted by Fed. R. App. P. 32(f) and Fed. Cir. R. 32(b)(2).

This brief complies with the typeface requirements of Fed. R. App. P. 32(a)(5) and the type style requirements of Fed. R. App. P. 32(a)(6) because this brief has been prepared in a proportionally spaced typeface using Microsoft Word for Microsoft 365 in Century Schoolbook 14-point font.

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